

# **Field Growth in the Super Giant Wattenberg Field, Denver Basin, Colorado\***

**Steve Sonnenberg<sup>1</sup>**

Search and Discovery Article #20468 (2019)\*\*  
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## **Abstract**

The giant Wattenberg Field area of Colorado was discovered in 1970 by Amoco Production Company and Vessels Oil and Gas with completions in the Lower Cretaceous Muddy (J) Sandstone. Wattenberg straddles the Denver Basin synclinal axis and is regarded as a basin-center stratigraphic petroleum accumulation. Additional production was encountered in five other formations during the development of the field (Plainview, Codell Sandstone, Niobrara Formation, Terry and Hygiene sandstone members of the Pierre Shale). The Terry and Hygiene were first produced in 1972; the Codell in 1981; the Niobrara in 1985; and the Plainview in 1998. Reservoir quality in the various horizons is generally poor which mandates hydraulic fracture stimulation for production. The greater Wattenberg area (GWA) covers approximately 2600 square miles. Production occurs from approximately 4000 to 8500 feet across the field. Cumulative production from the field is 812 MMBO and 7.5 TCFG from over 35,000 wells.

The field is currently at peak production due to recent horizontal drilling activity in the Codell and Niobrara. Original reserves were estimated to be 1.1 TCFG for the J Sandstone. The addition of multiple productive horizons in the field area has significantly added to the total reserve number. The field is ranked by the EIA based on reserves as the fourth largest oil field and the ninth largest gas field in the US. Source beds for oil and gas in Wattenberg are the Skull Creek Shale, Graneros Shale, Greenhorn Limestone, Carlile Formation, Niobrara Formation, and Sharon Springs Member of the Pierre Shale. The Wattenberg area is a “hot spot” or positive temperature anomaly. This is an important reason the area is so prolific. Temperature gradients range from 16-18° F/1000 feet on the edges of the field to about 28-29° F/1000 feet in high GOR areas. The temperature anomaly is related to where the Colorado Mineral Belt intersects the Denver Basin. The mineral belt is a northeast trending zone across Colorado, of Late Cretaceous to Early Tertiary mineralization. The mineralization is associated with high geothermal gradients and hot fluids.

## **Selected References**

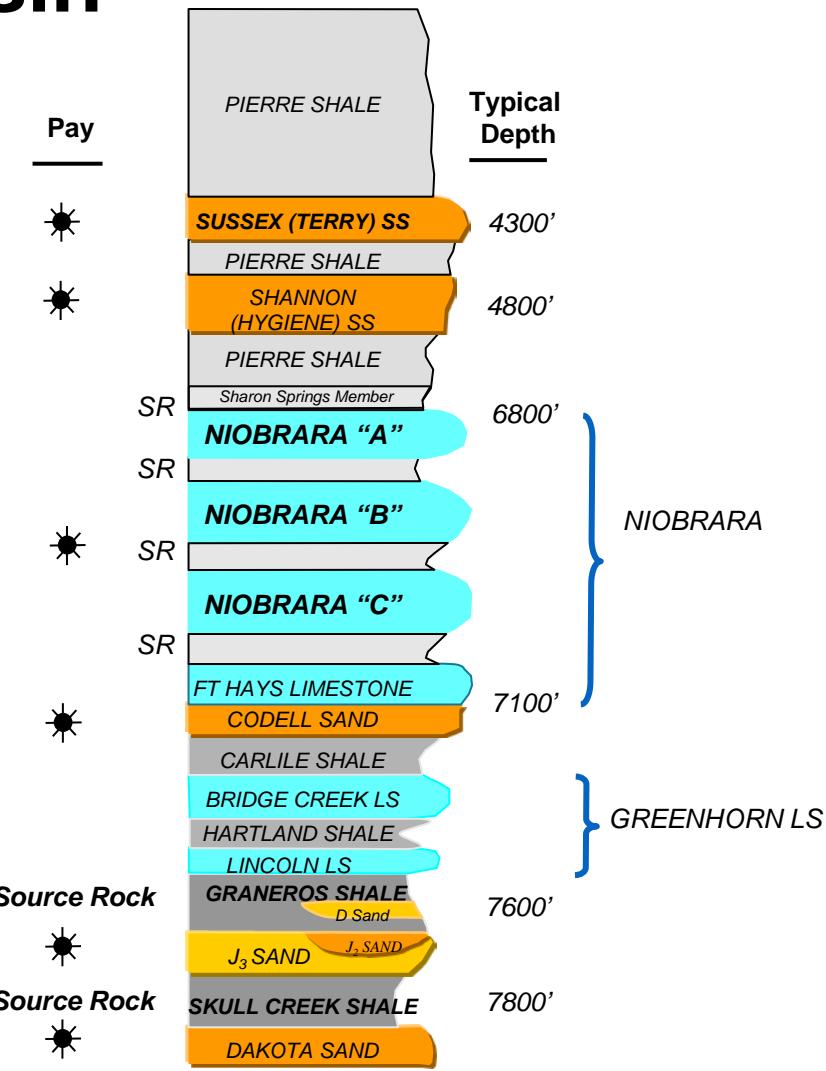
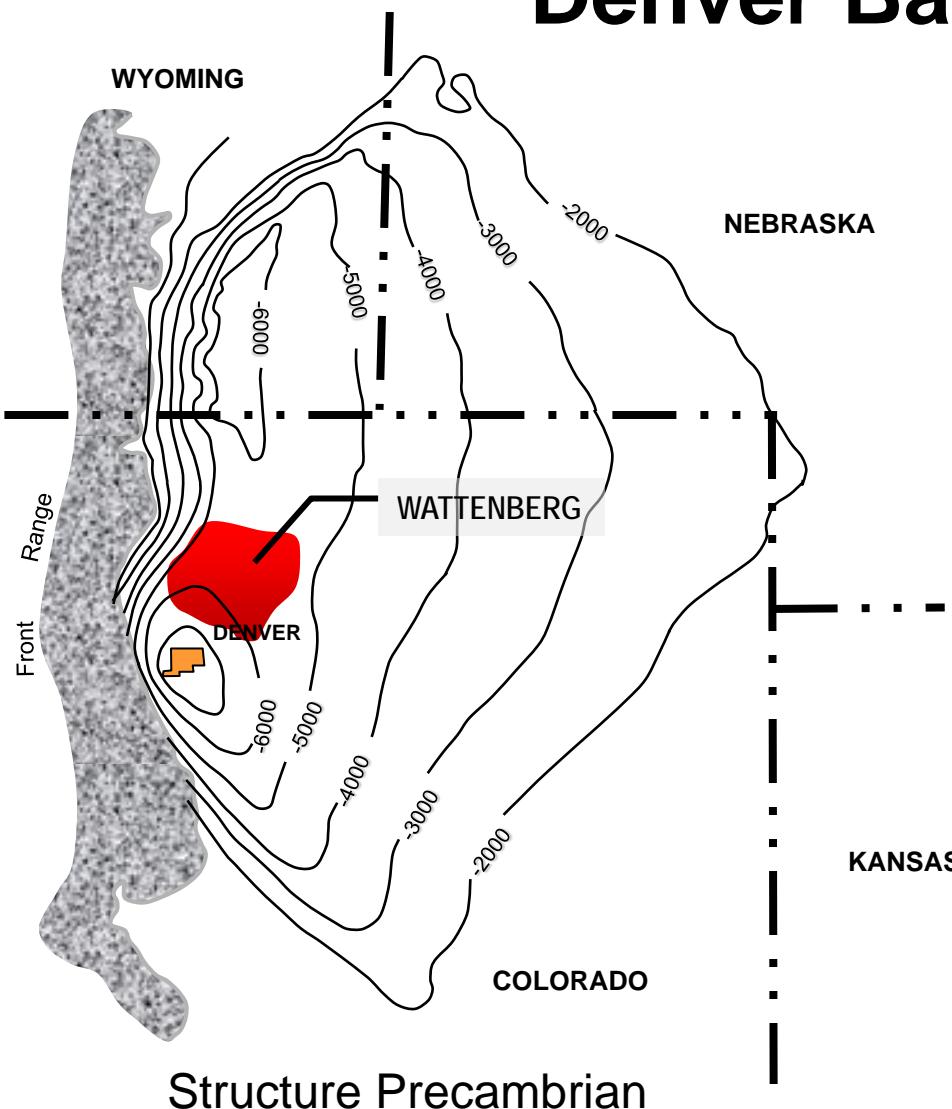
Matusczak, R.A., 1973, Wattenberg field, Denver basin, Colorado: Mountain Geologist, v. 10/3, p. 99-105.

Pagano, T.A., 2006, Rock properties, deliverability mechanism influence Codell restimulation: Oil and Gas Journal, 10 p.

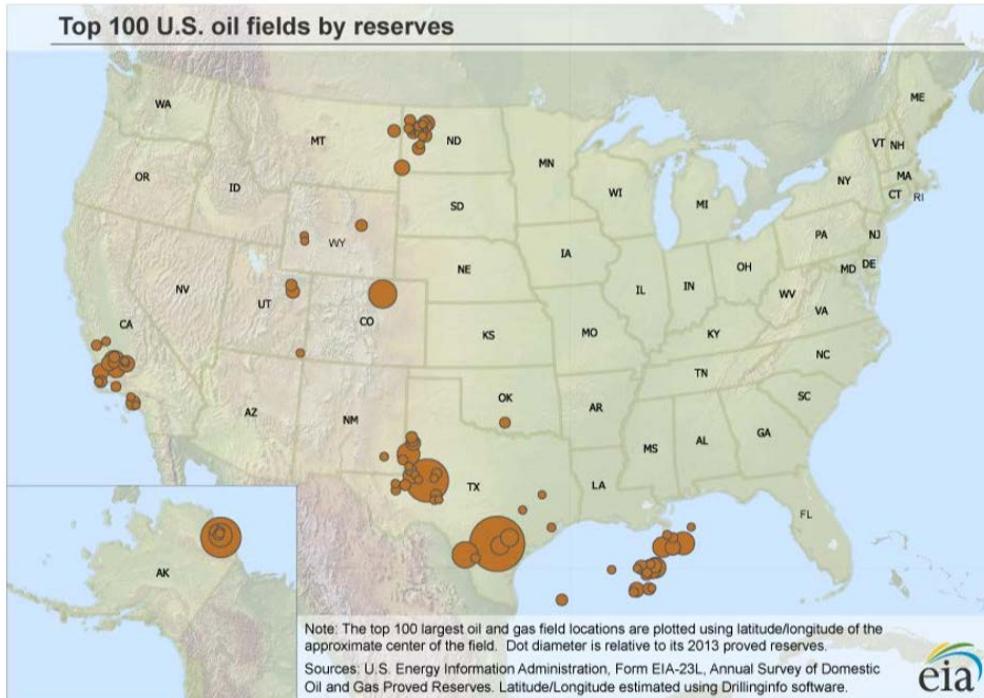
# Field Growth in the Super Giant Wattenberg Field, Denver Basin, Colorado

Dr. Steve Sonnenberg  
Colorado School of Mines

# Denver Basin



## Top 100 U.S. oil fields by reserves

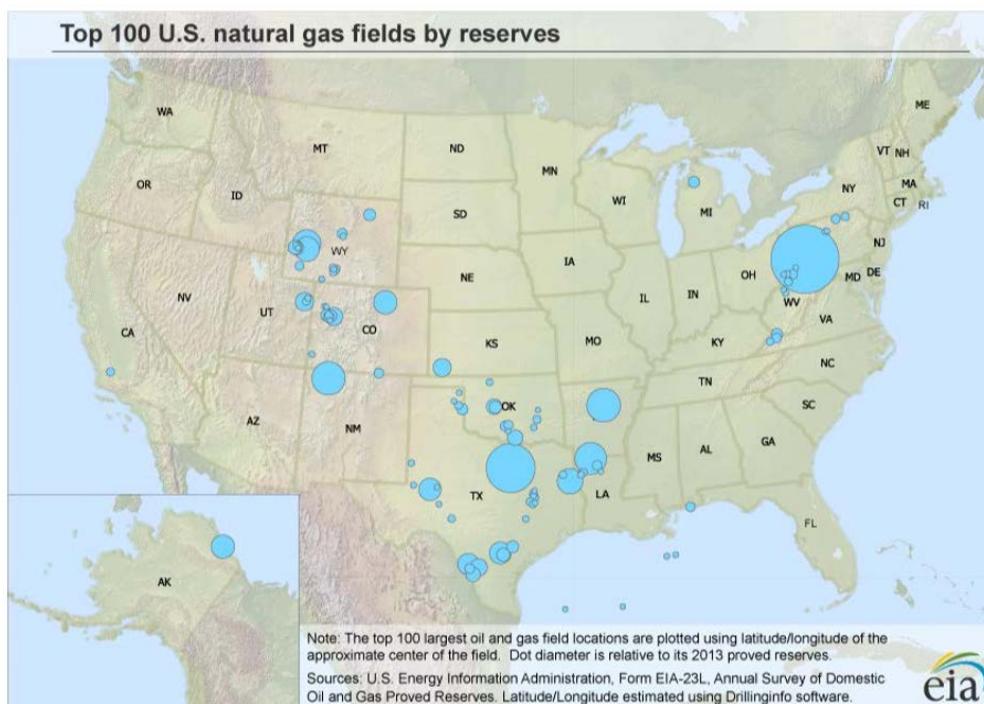


## Wattenberg Field EIA top 10 Oil and Gas Field

### Top 10 Oil Fields

1. Eagleville (TX) – 238 million barrels
2. Spraberry (TX) – 99 million barrels
3. Prudhoe Bay (AK) – 79 million barrels
4. Wattenberg (CO) – 47 million barrels
5. Briscoe Ranch (TX) – 62 million barrels
6. Kuparuk River (AK) – 29 million barrels
7. Mississippi Canyon (Fed Gulf) – 15 million barrels
8. Wasson (TX) – 19 million barrels
9. Belridge South (CA) – 23 million barrels
10. Green Canyon (Fed Gulf) – 27 million barrels

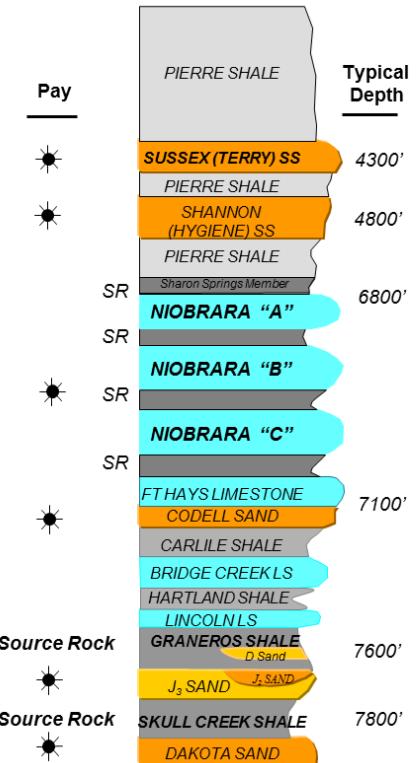
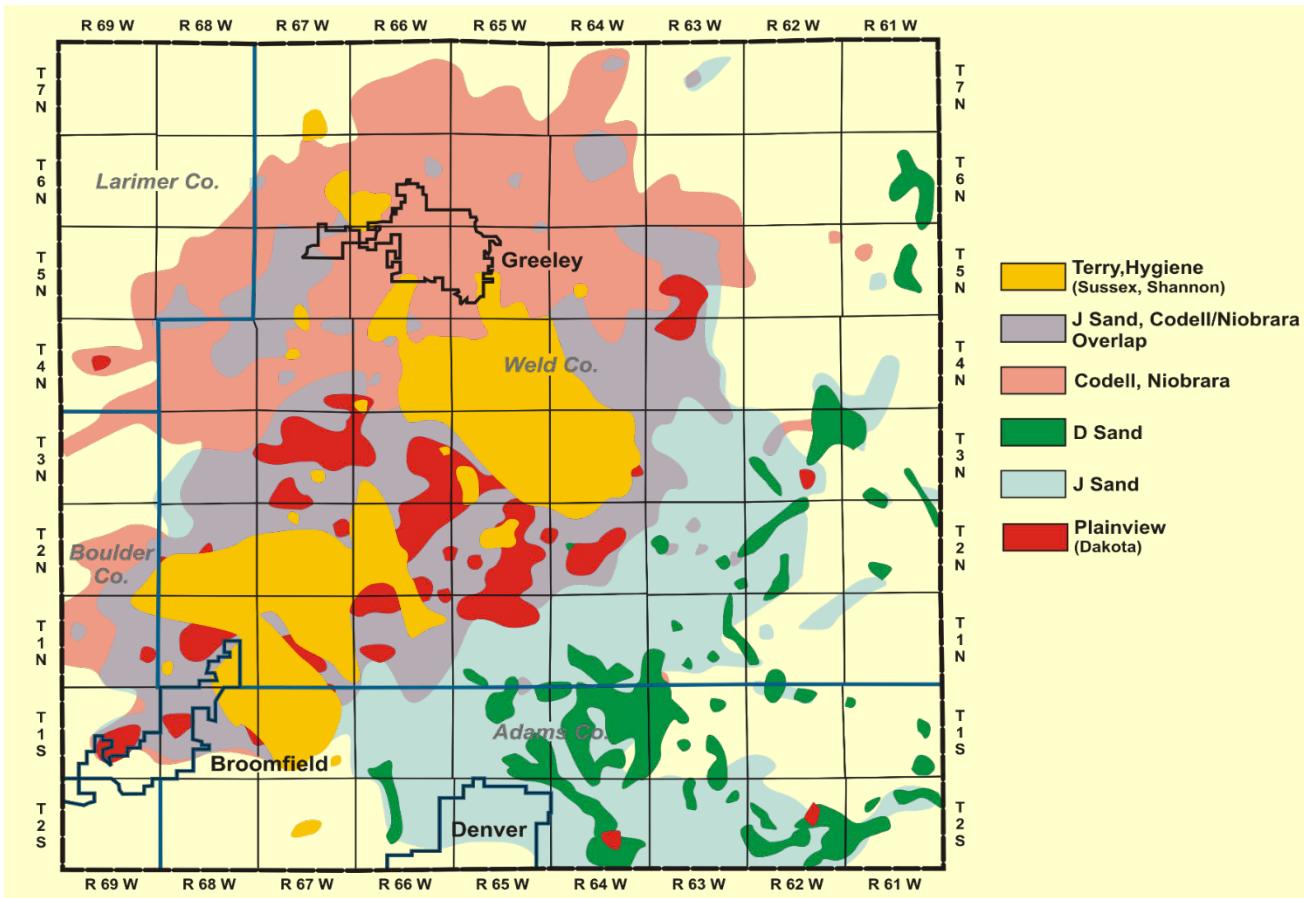
## Top 100 U.S. natural gas fields by reserves



### Top 10 Natural Gas Fields

1. Marcellus Shale (PA & WV) – 2,836 billion cubic feet
2. Newark East (TX) – 1,951 billion cubic feet
3. B-43 Area (AR) – 1,025 billion cubic feet
4. San Juan Basin (CO & NM) – 1,024 billion cubic feet
5. Haynesville Shale (LA) – 1,425 billion cubic feet
6. Pinedale (WY) – 568 billion cubic feet
7. Carthage (TX) – 653 billion cubic feet
8. Jonah (WY) – 239 billion cubic feet
9. Wattenberg (CO) – 304 billion cubic feet
10. Prudhoe Bay (AK) – 147 billion cubic feet

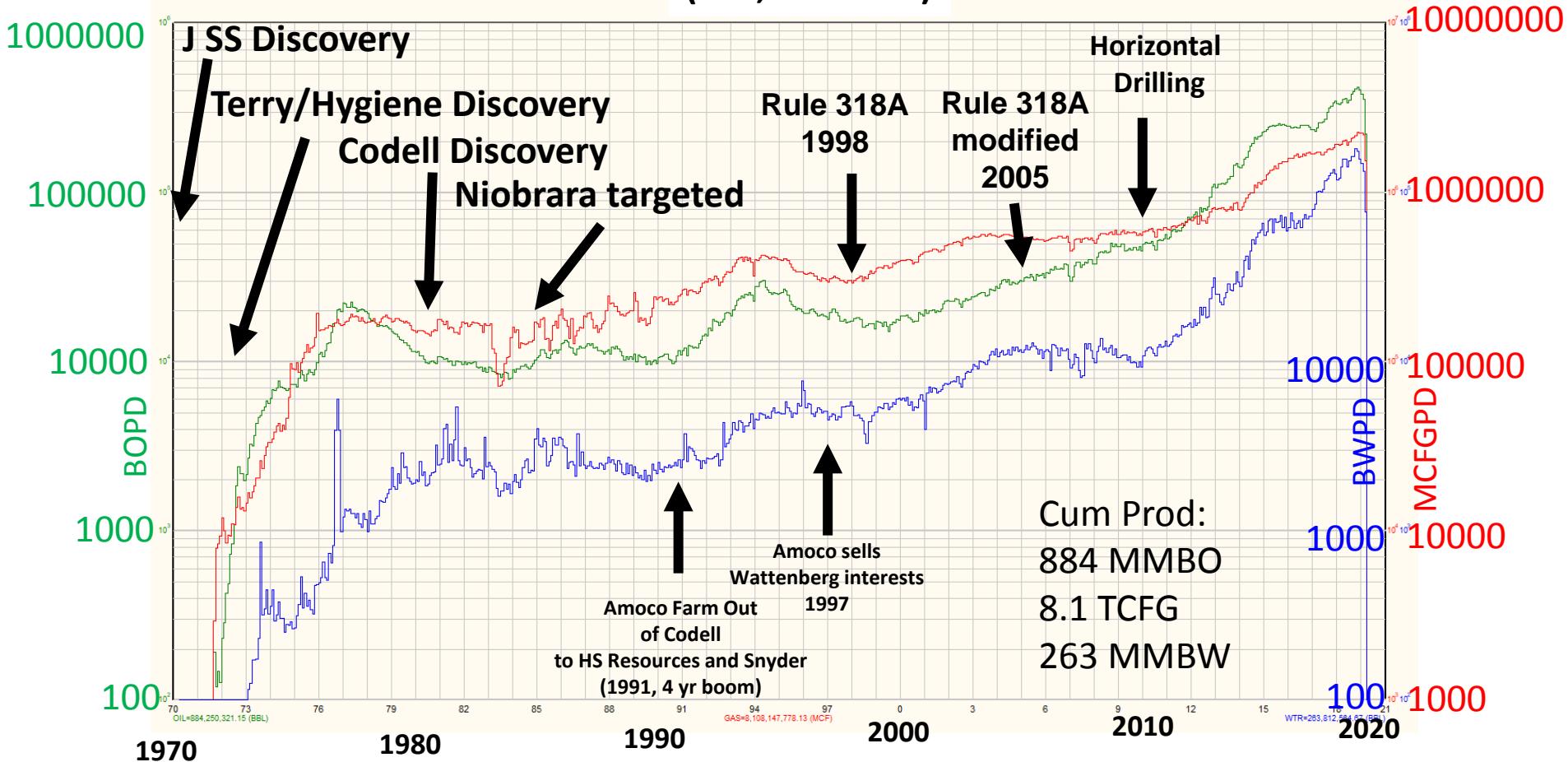
# Productive Areas-GWA



Wright, 2005; Modified after Ladd, 2001

# Wattenberg Field Production

(~40,000 wells)





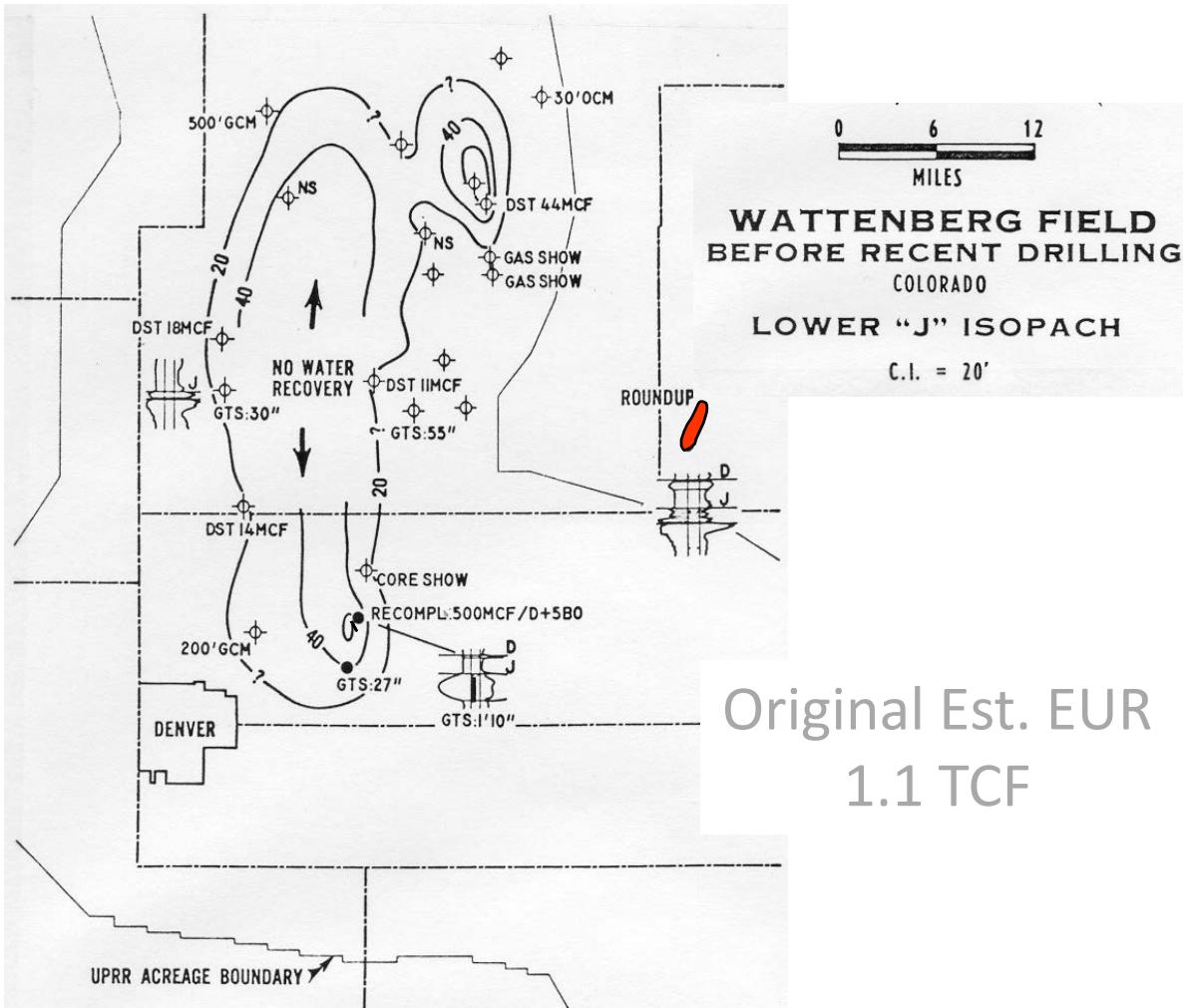
**Steve Sonnenberg**

**Pete Matusczak**

**Bob Weimer**

Circa, 2005

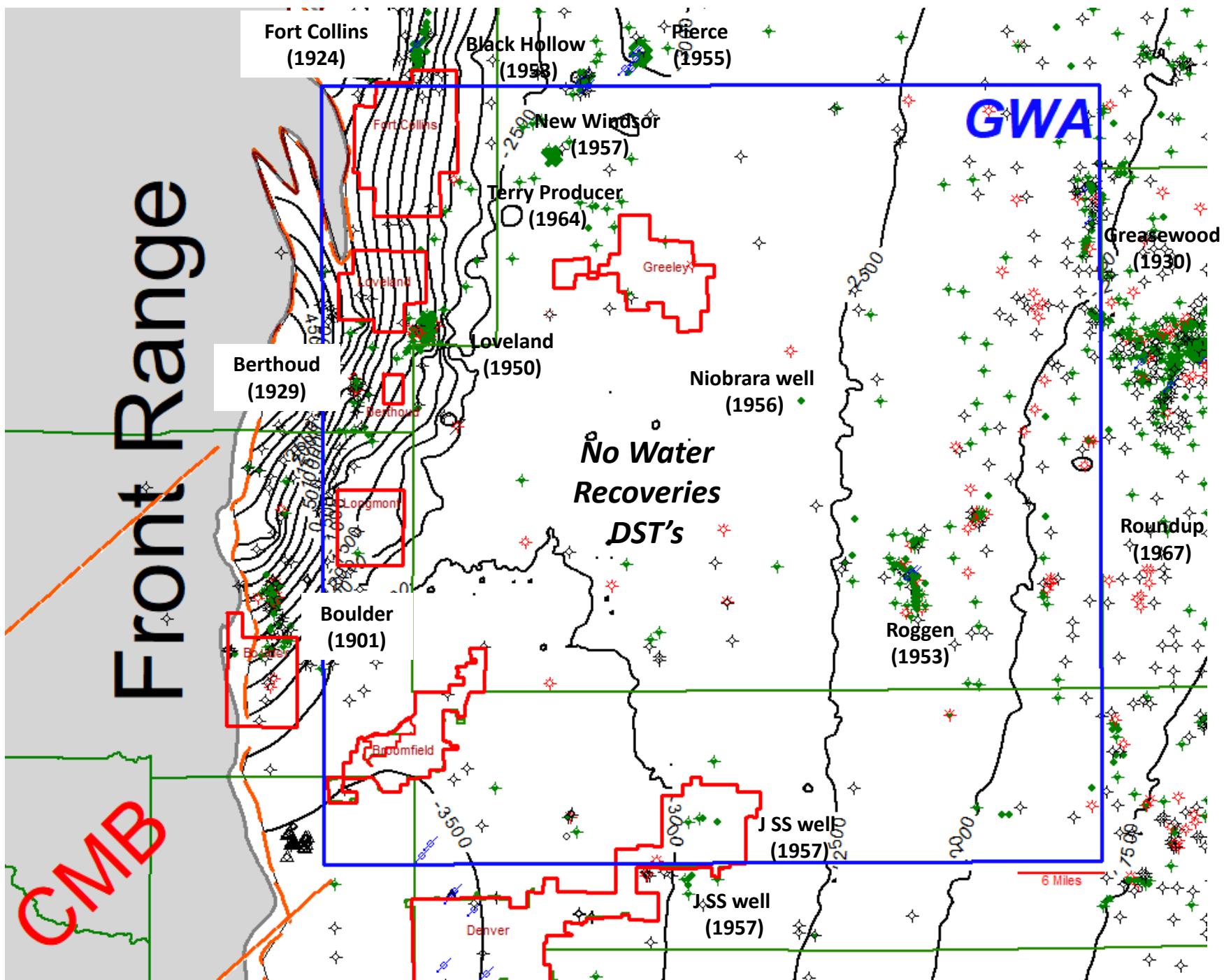
# History of Wattenberg Gas Field

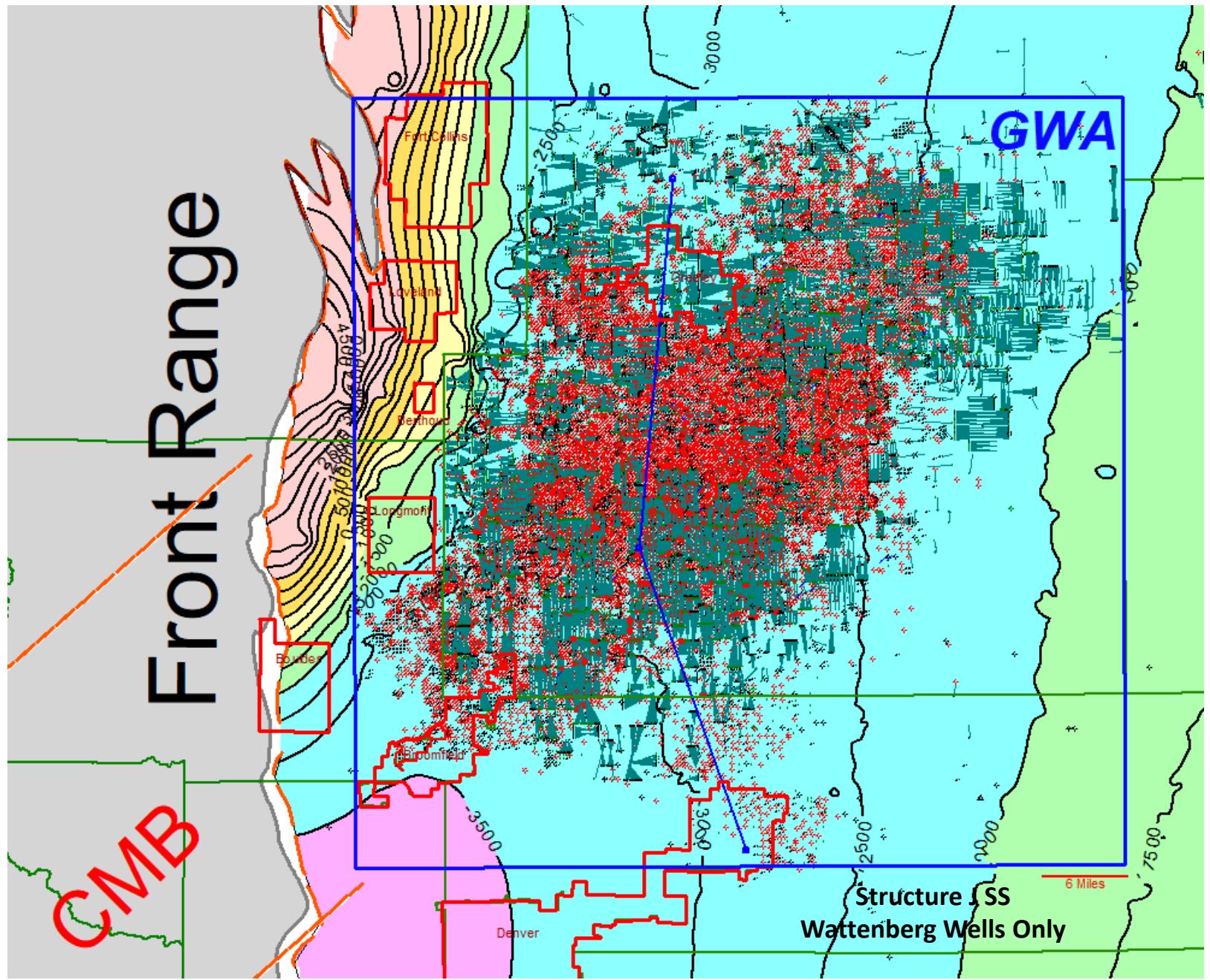


## A Near Miss!

- All DSTs or cores taken in the J indicated shows of gas
- Core analyses of the J compared with those of the Dakota in the SJB
- Old wells in area remarkably similar
- Earlier discovery at Roundup - 1967
- Wattenberg discovered - 1970

# Front Range



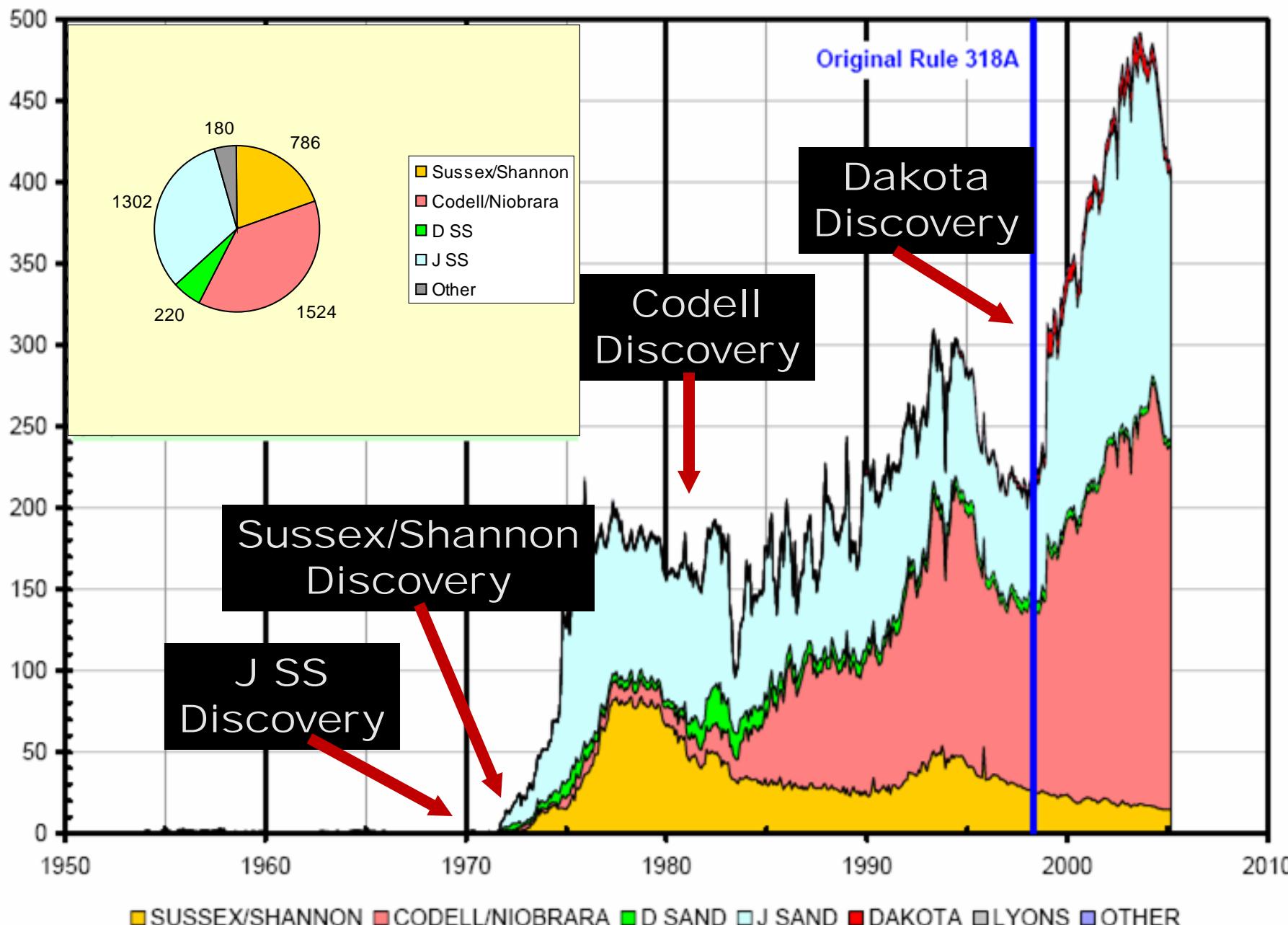


# GWA Spacing History

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- 1970: 320 acre units for drilling & spacing of J Sand
- 1979: Additional J Sand well allowed per 320 acre unit
- 1980: Section 29 tax credit; Tight gas sand designation (exp. 2002)
- 1983: Codell spaced on 80 acre
- 1984,85: Niobrara added to Codell spacing order
- 1991: J Sand wells can be recompleted to C-N & commingling of all downhole zones allowed
- 1998: Rule 318A allows 5 wells per quarter section in GWA for all Cretaceous age formations (81 townships)(32 acre spacing)
- 2005: Rule 318A modified to allow for section line & quarter section line wells (~ 20 acre spacing 27 townships)

DAILY GAS PRODUCTION; MMCFPD



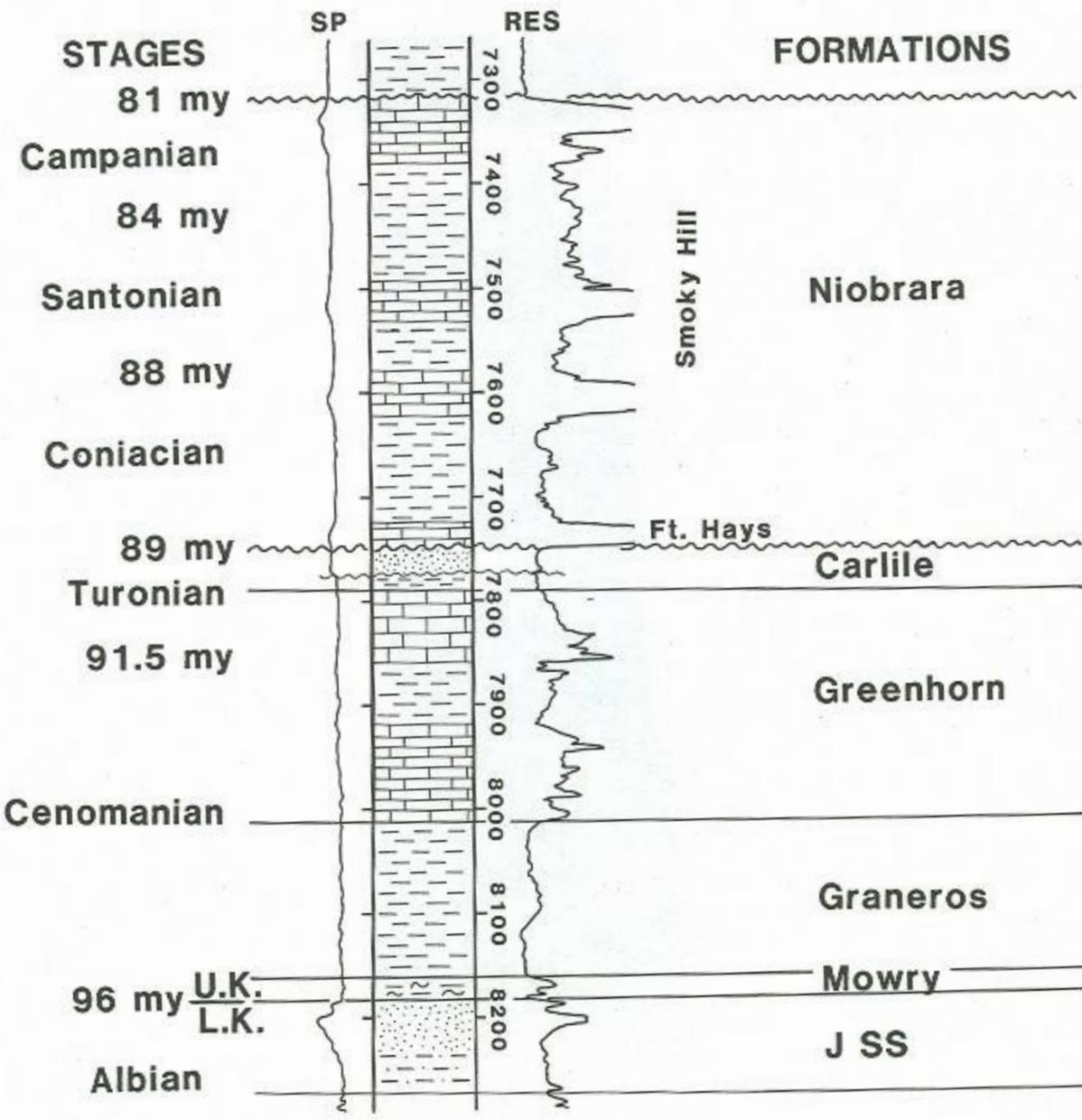
■ SUSSEX/SHANNON ■ CODELL/NIOBARARA ■ D SAND ■ J SAND ■ DAKOTA ■ LYONS ■ OTHER

Wright, 2005

# History & The Various Companies (+/- 40)

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- Early (1970s): Amoco and Vessels
- Codell (1981): Energy Oil
- Price collapse mid-1980s
- Price recovery and tight gas sand credits late 1980s
- Late 1980s: Gerrity, Snyder, Martin Exploration, Prima, Basin, HS Resources
- 1991: Amoco farm out Codell to HS Resources and Snyder
- Amoco sells Wattenberg to HS 1997; Patina forms 1996 (consolidation of Snyder and Gerrity properties); Noble acquires Patina in 2005
- Current companies: Anadarko, Noble, PDC, Crestone Peak, Extraction, etc.



# Wattenberg Key Ingredients

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- Geothermal anomaly
- Basin Center Continuous Accumulation
- Paleostructure -- The Wattenberg High

# Continuous Accumulations (Muddy “J”, Codell, Niobrara)

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- Pervasive accumulations that are hydrocarbon saturated
- Not localized by buoyancy
- No down-dip hydrocarbon/water contact
- Updip contact with regional water saturation
- Some water production
- Abnormally pressured (+ or -)
- Production independent of structural closure
- Low  $\phi$  & K reservoirs
- Sweet spots controlled by fractures & matrix
- Associated with mature source rocks that are either actively generating or have recently ceased generation
- Hydrocarbons of thermal origin
- Fields have diffuse boundaries
- Inverted Petroleum Systems

COQUINA OIL CORP  
BERTHOUD-STATE  
3

T4N R69W S16  
NE SW

NOBLE ENERGY PROD  
JEFFERS  
42-35

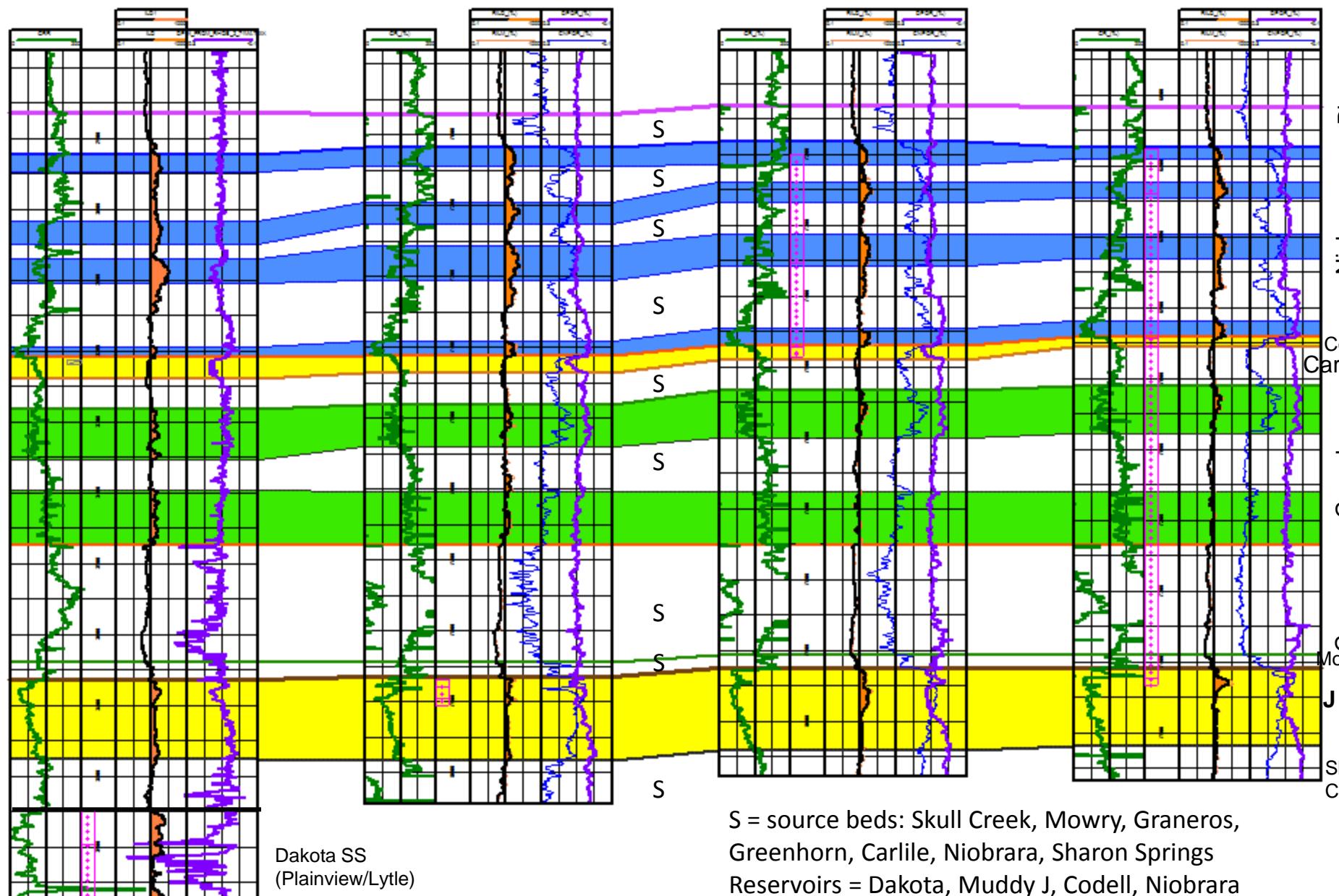
T4N R68W S35  
NW SE NE

KERR-MCGEE O&G ON LP  
ROBERTS  
37-22

T3N R68W S22  
SW SW SE

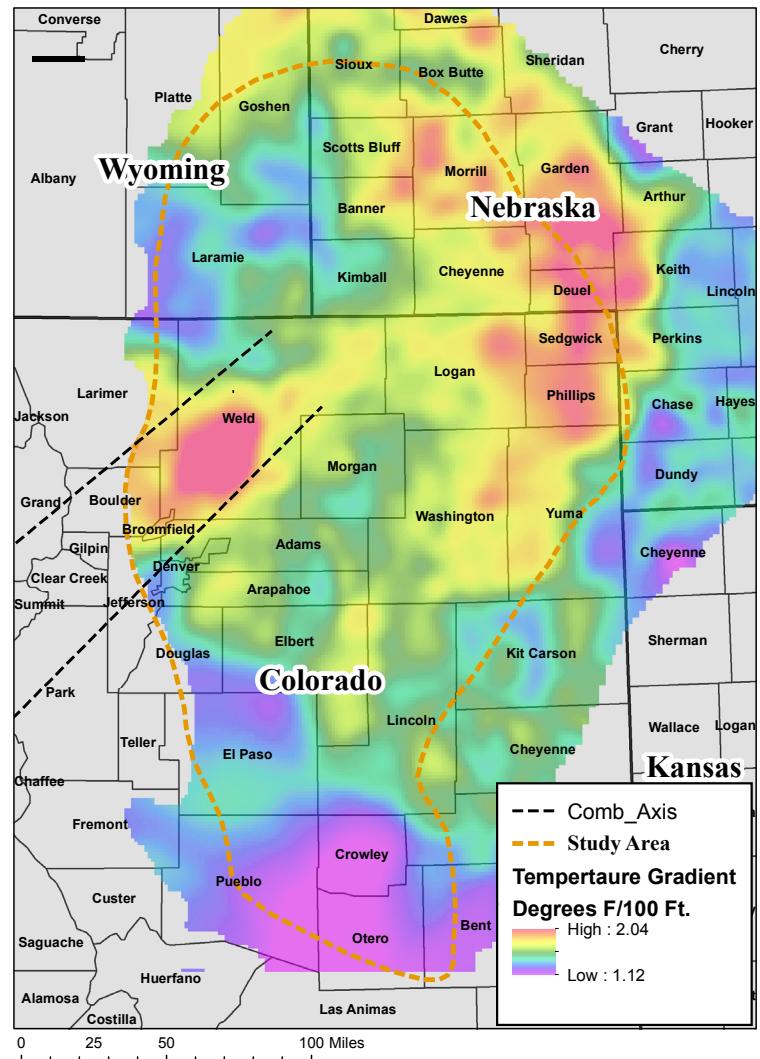
NOBLE ENERGY INC  
FRONT RANGE D  
9-33

T3N R64W S9  
W2 SW

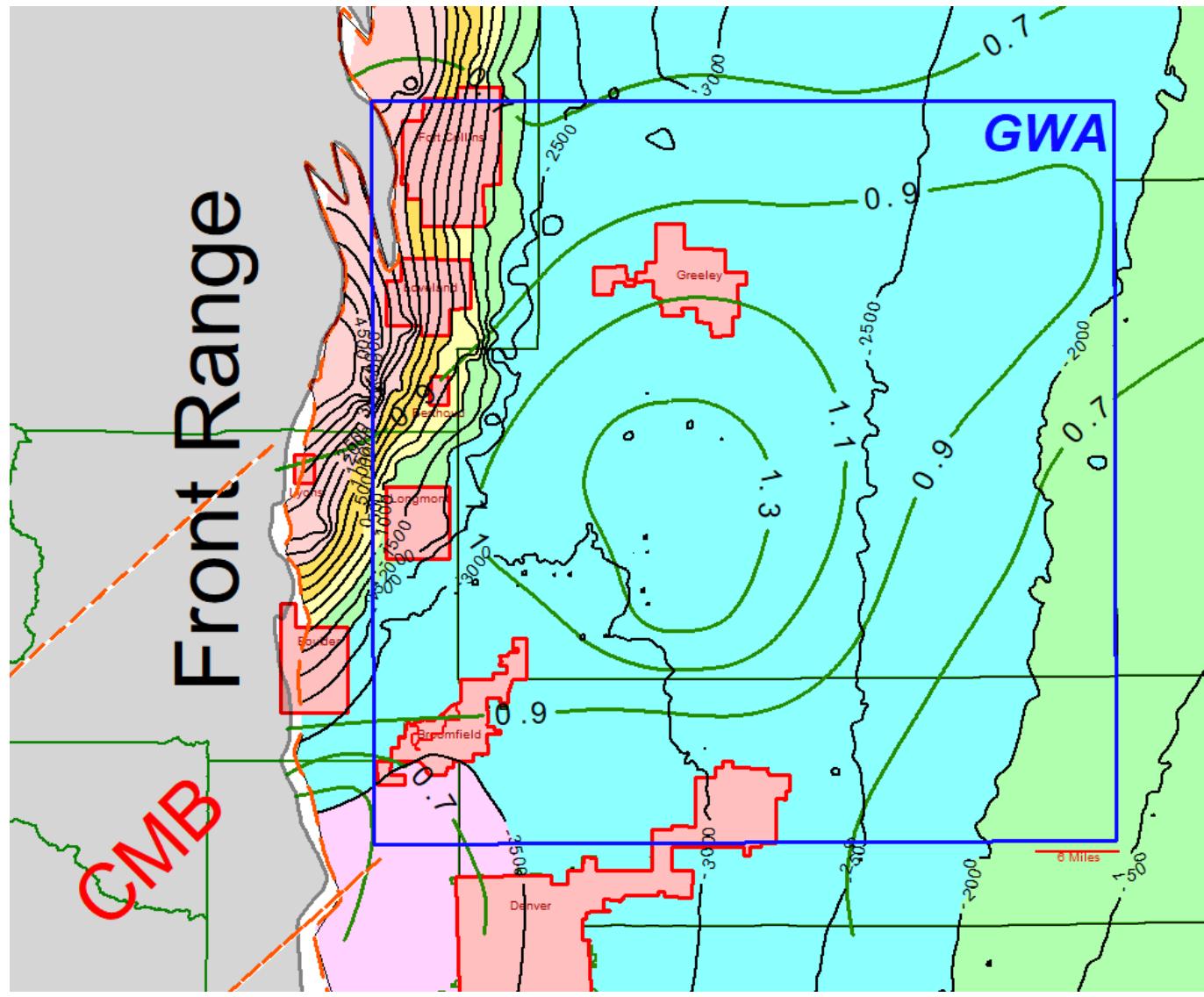


# Wattenberg Thermal Anomaly

- Related to igneous masses in basement
- Located where CMB intersects Denver Basin
- Direct temperature measurements in wells
- Ro values
- GORs

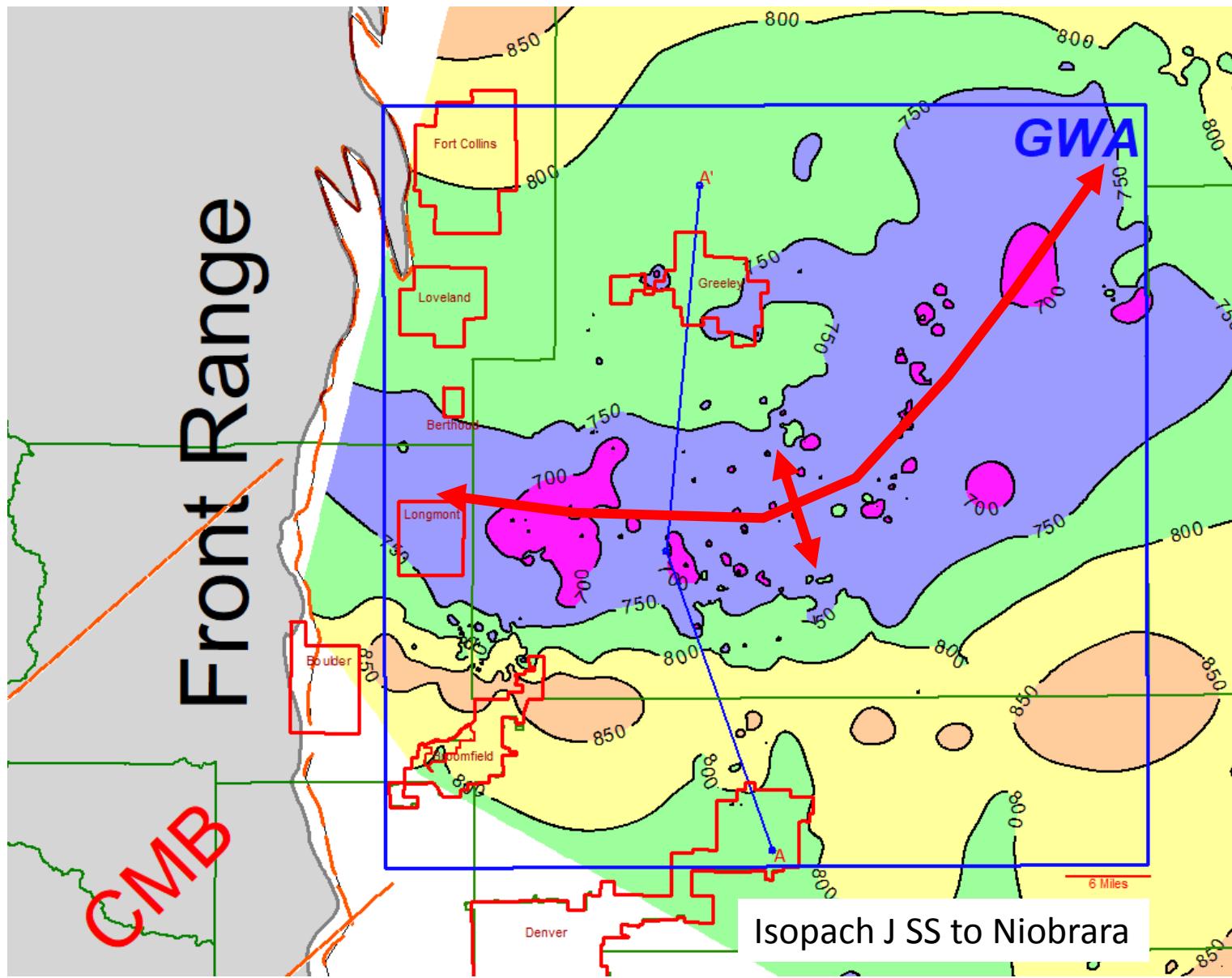


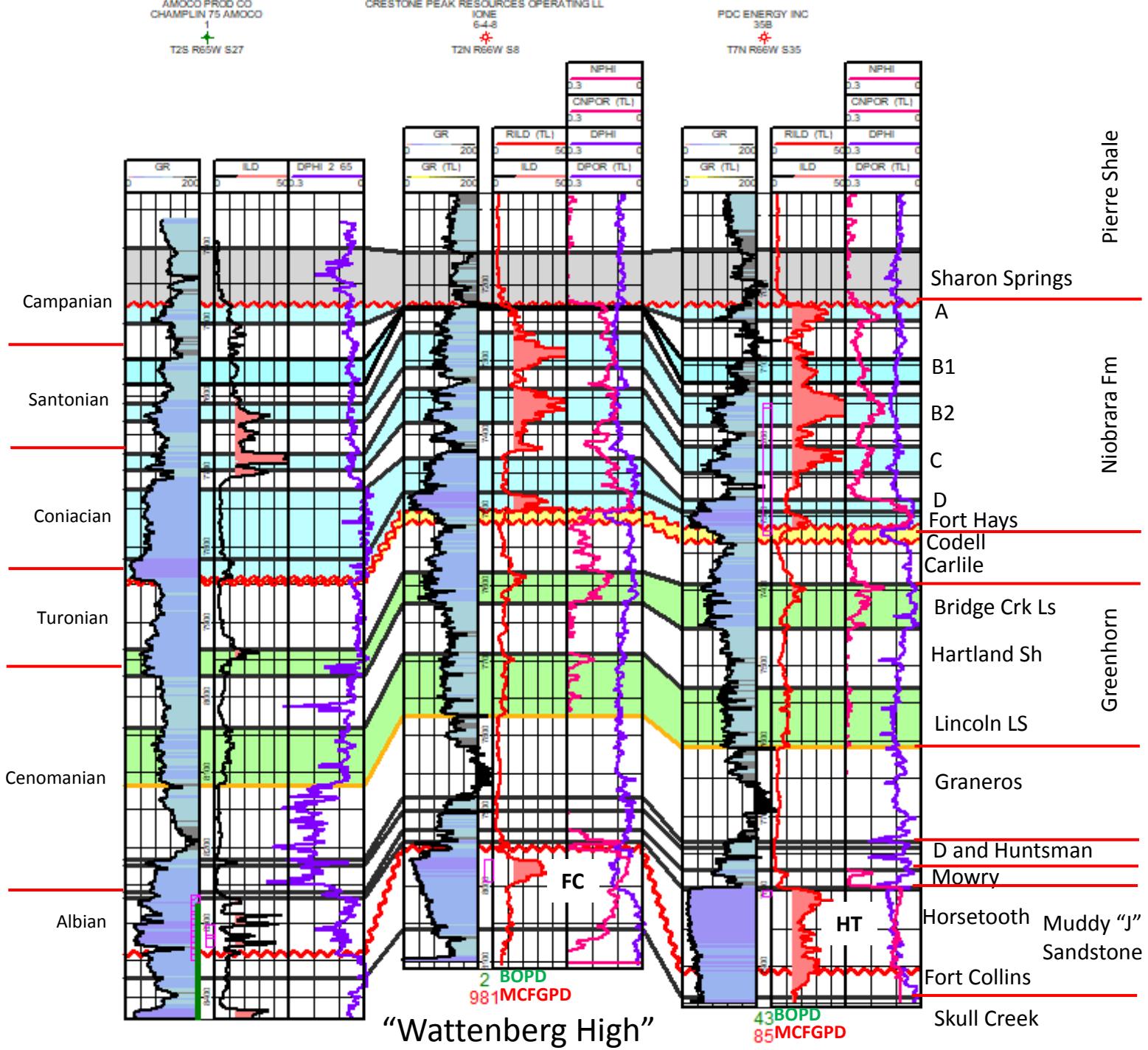
Thul and Sonnenberg, 2018



Structure Muddy J Sandstone and Ro

	Pay	Typical Depth
●	SUSSEX (TERRY) SS	4300'
●	PIERRE SHALE	4800'
●	SHANNON (HYGIENE) SS	
●	PIERRE SHALE	
SR	Sharon Springs Member	6800'
SR	<b>NIOBRARA "A"</b>	
●	<b>NIOBRARA "B"</b>	
SR	<b>NIOBRARA "C"</b>	
●	FTHAYS LIMESTONE	7100'
●	CODELL SAND	
●	CARLILE SHALE	
●	BRIDGE CREEK LS	
●	HARTLAND SHALE	
●	LINCOLN LS	
●	GRANEROS SHALE	
●	D Sand	7600'
●	J <sub>3</sub> SAND	
●	J <sub>3</sub> SAND	
Source Rock	SKULL CREEK SHALE	7800'
Source Rock	DAKOTA SAND	

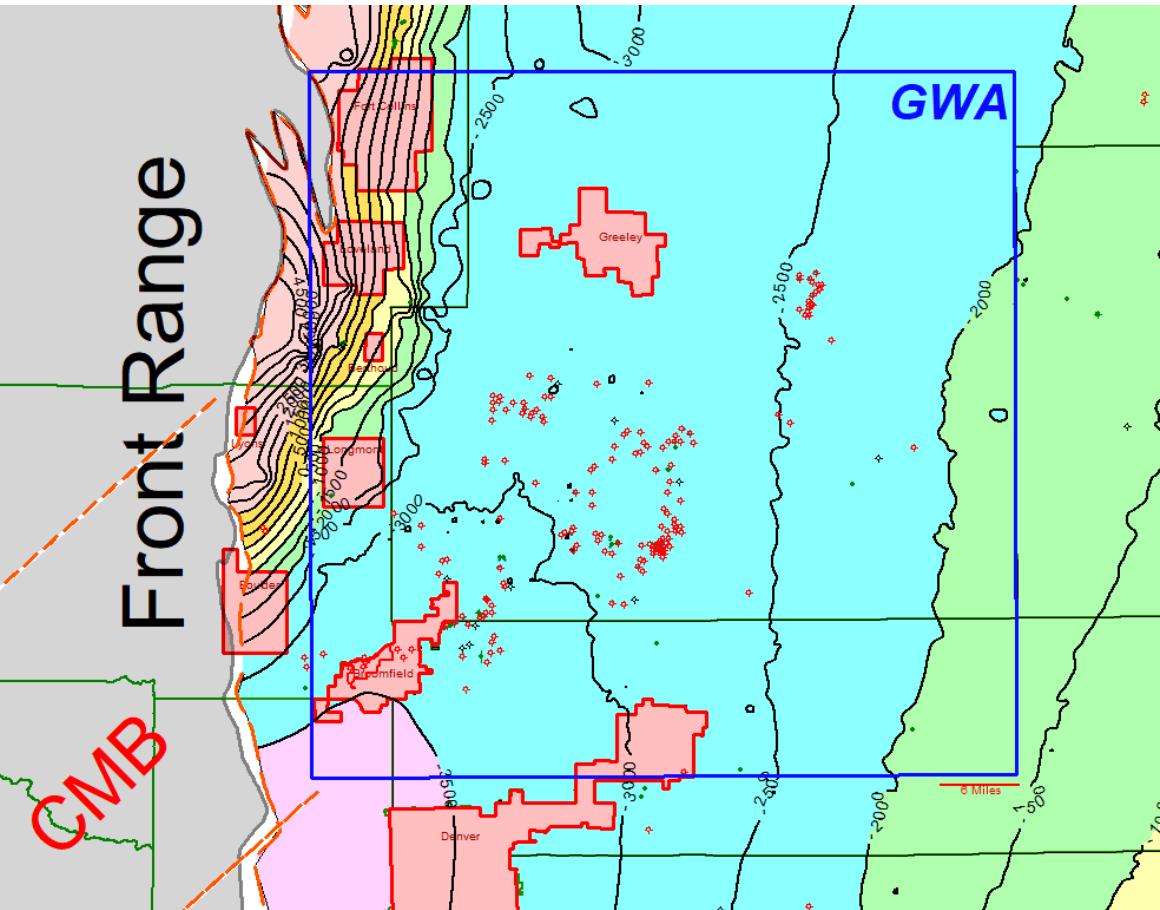




# Basic reservoir data, Plainview/Lytle

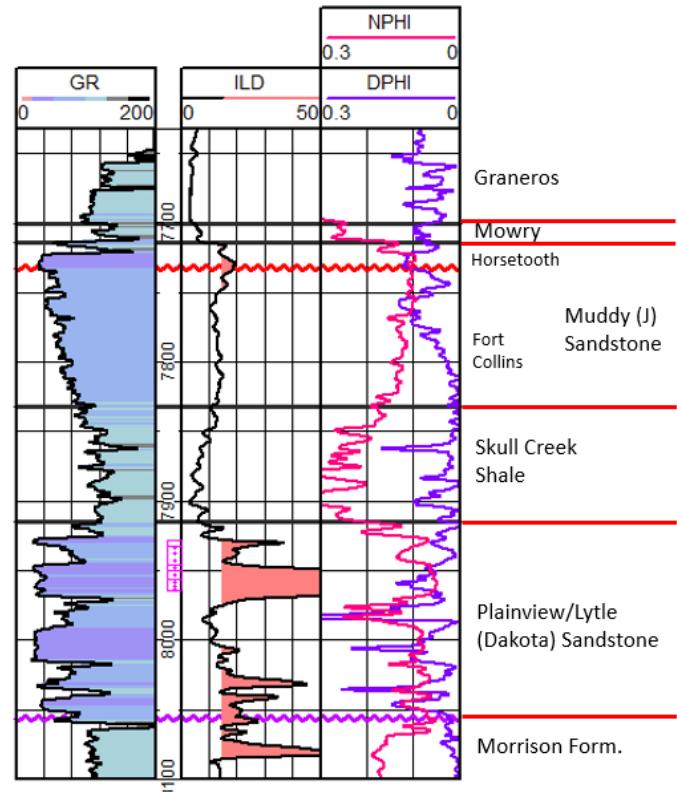
• Average Porosity	8-10%
• Average Permeability	0.1 – 0.2 md
• Connate Water Saturation	40-50%
• Current Field Size	800,000 acres
• Pay thickness	10-30 ft
• Original Reservoir Pressure	2800 psi
• Depth Range	7000 to 8,500 ft
• Initial Potentials	100 to 1,000 Mcf
• Original Spacing	320
• Current Spacing	20
• Cumulative Prod:	2,032,436 BO 87,015,478 MCF

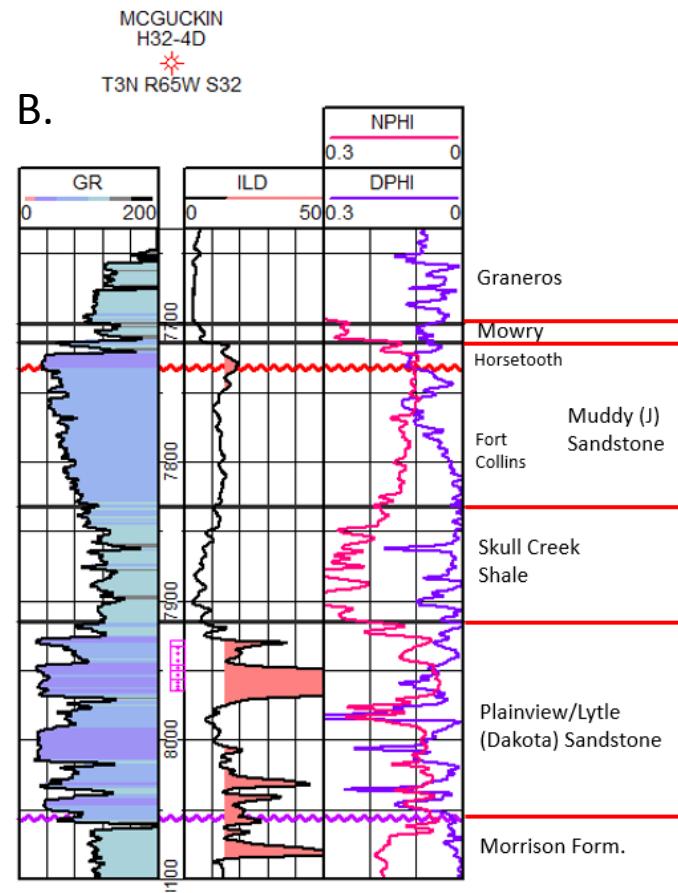
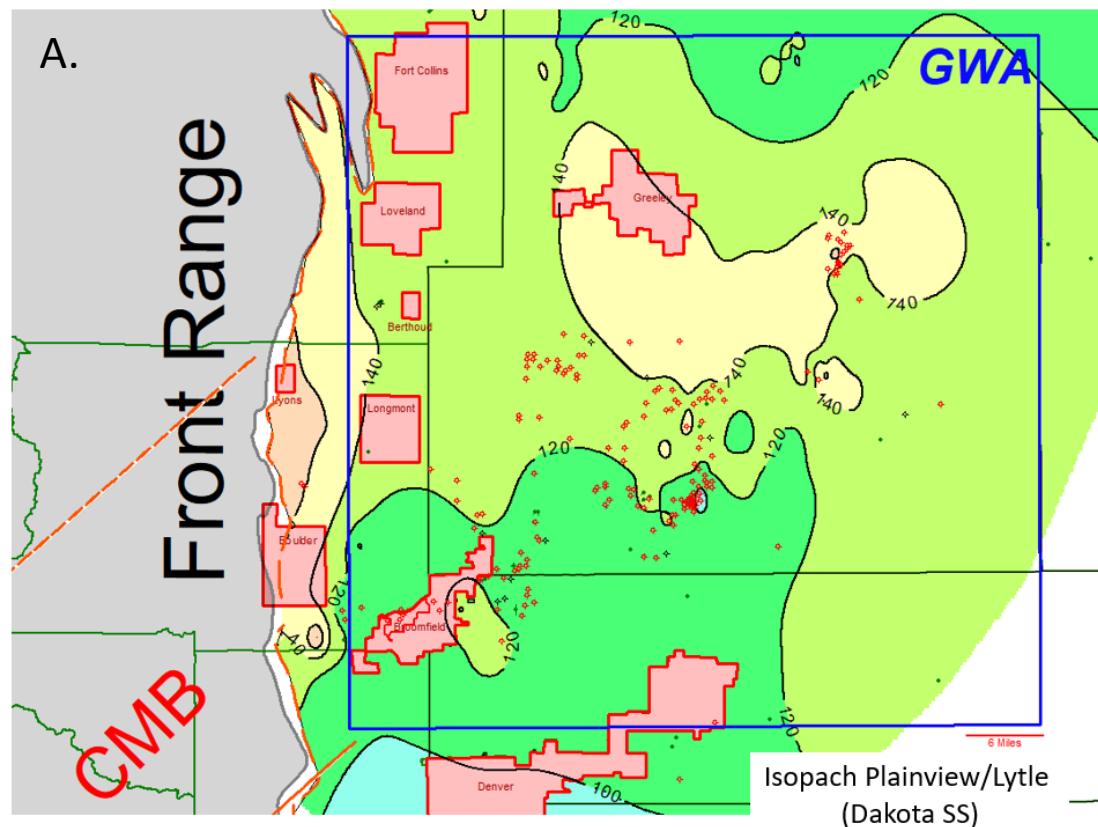
# Front Range



Structure Muddy SS & Dakota Producers

MCGUCKIN  
H32-4D  
T3N R65W S32

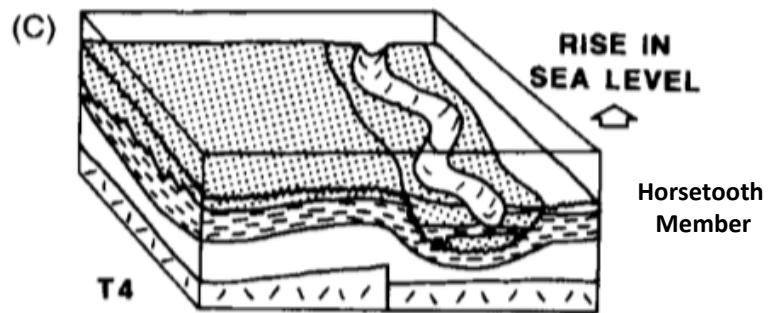
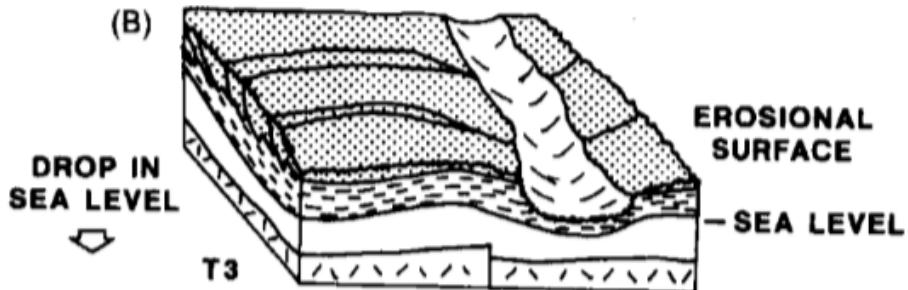
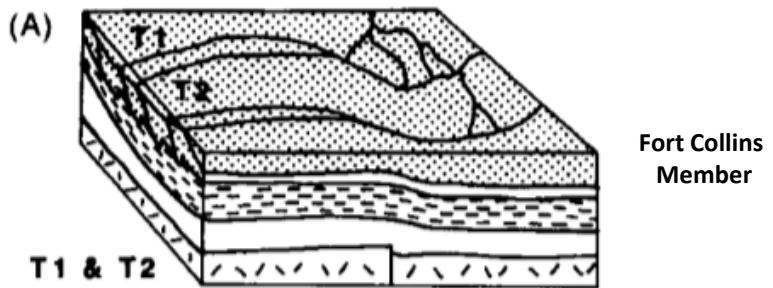




# Basic reservoir data, Muddy "J" SS

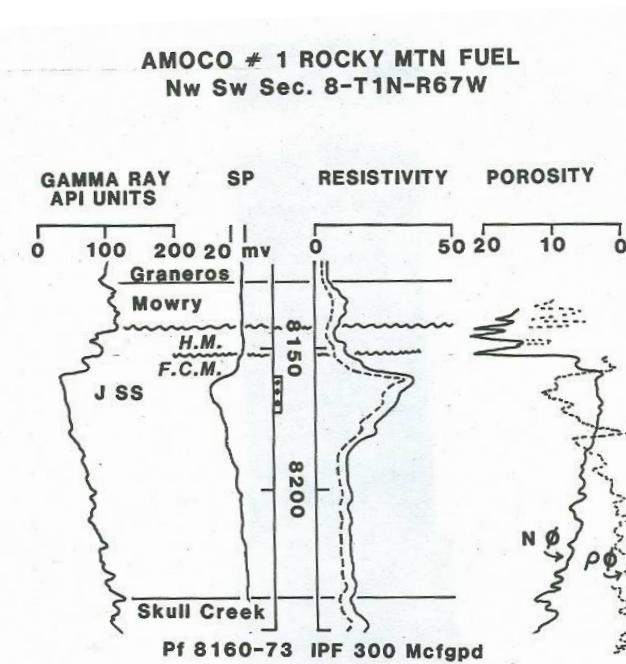
• Average Porosity	9.5%
• Average Permeability	0.1 – 0.2 md
• Port $r_{35}$	0.19 $\mu\text{m}$
• Connate Water Saturation	44%
• Recoverable Reserves (1970)	1,100 BCF
• Recoverable Reserves	3,100 BCF
• Field Size (1970)	283,000 acres
• Current Field Size	800,000 acres
• Average Pay thickness	25 ft
• Original Reservoir Pressure	2,750 psi
• Depth Range	7,400–8,500 ft
• Initial Potentials	100--3,575 Mcfgpd
• Original Spacing	320 acres
• Current Spacing	~ 20 acre

Modified from Matusczak, 1973



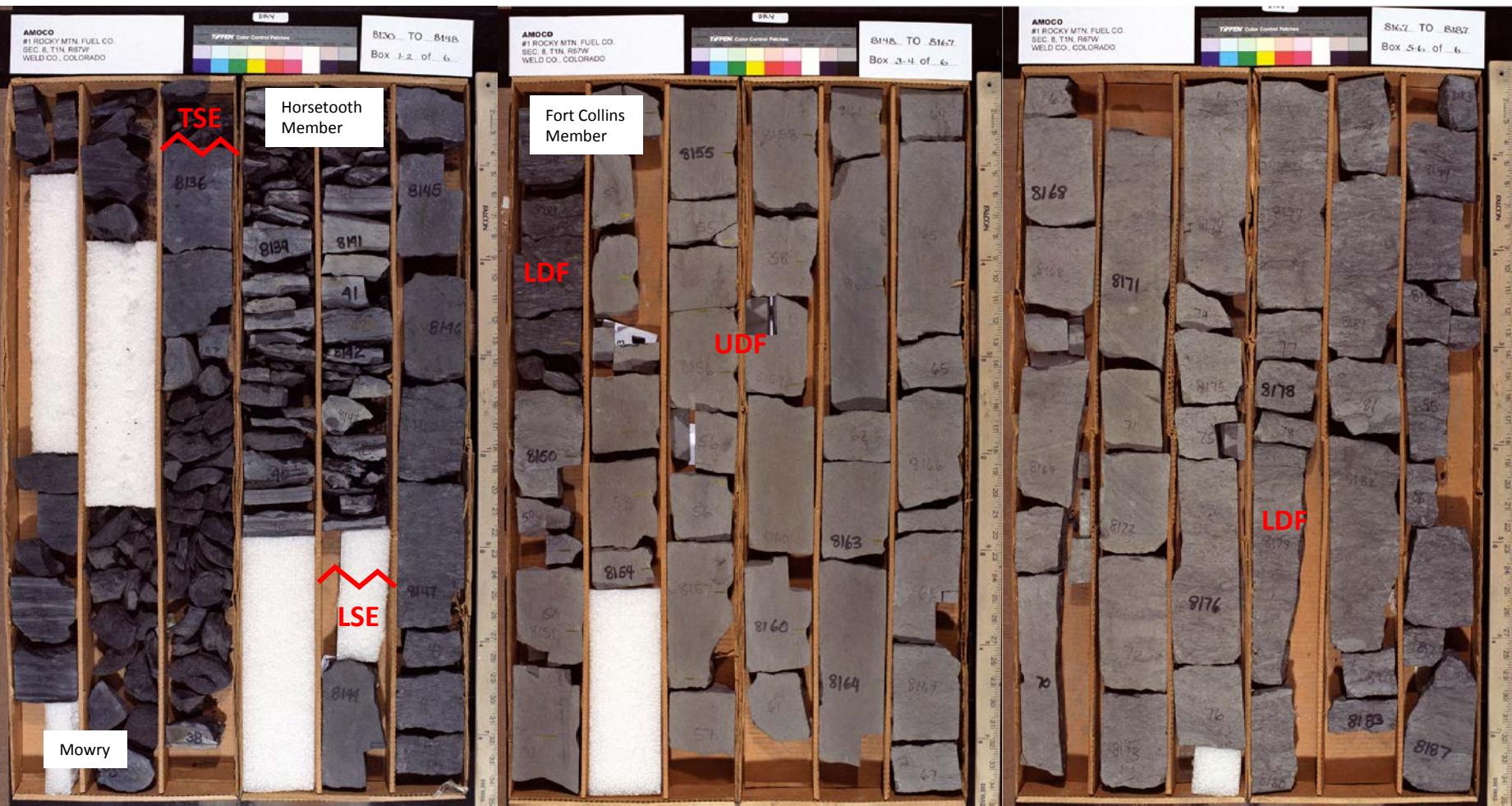
### Valley Fill Model Muddy (J) Sandstone

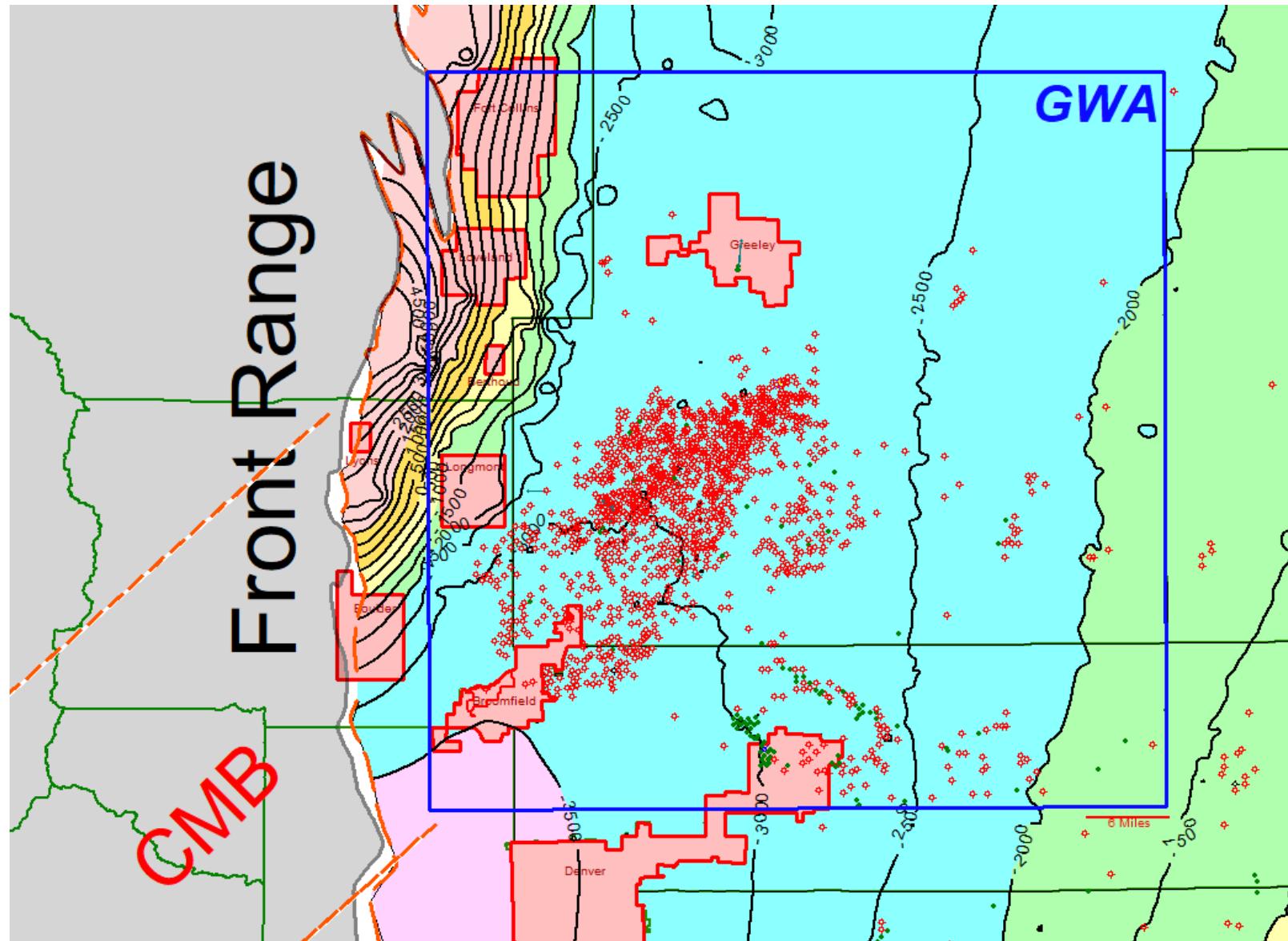
- A. Wave-dominated deltaic progradation during highstand (Fort Collins Mbr)
- B. Drop in sea level; erosional drainages; lowstand
- C. Sea level rise; backfilling of valley networks (Horsetooth Mbr; fluvial and marine strata)



# Amoco # 1 Rocky Mountain Fuel

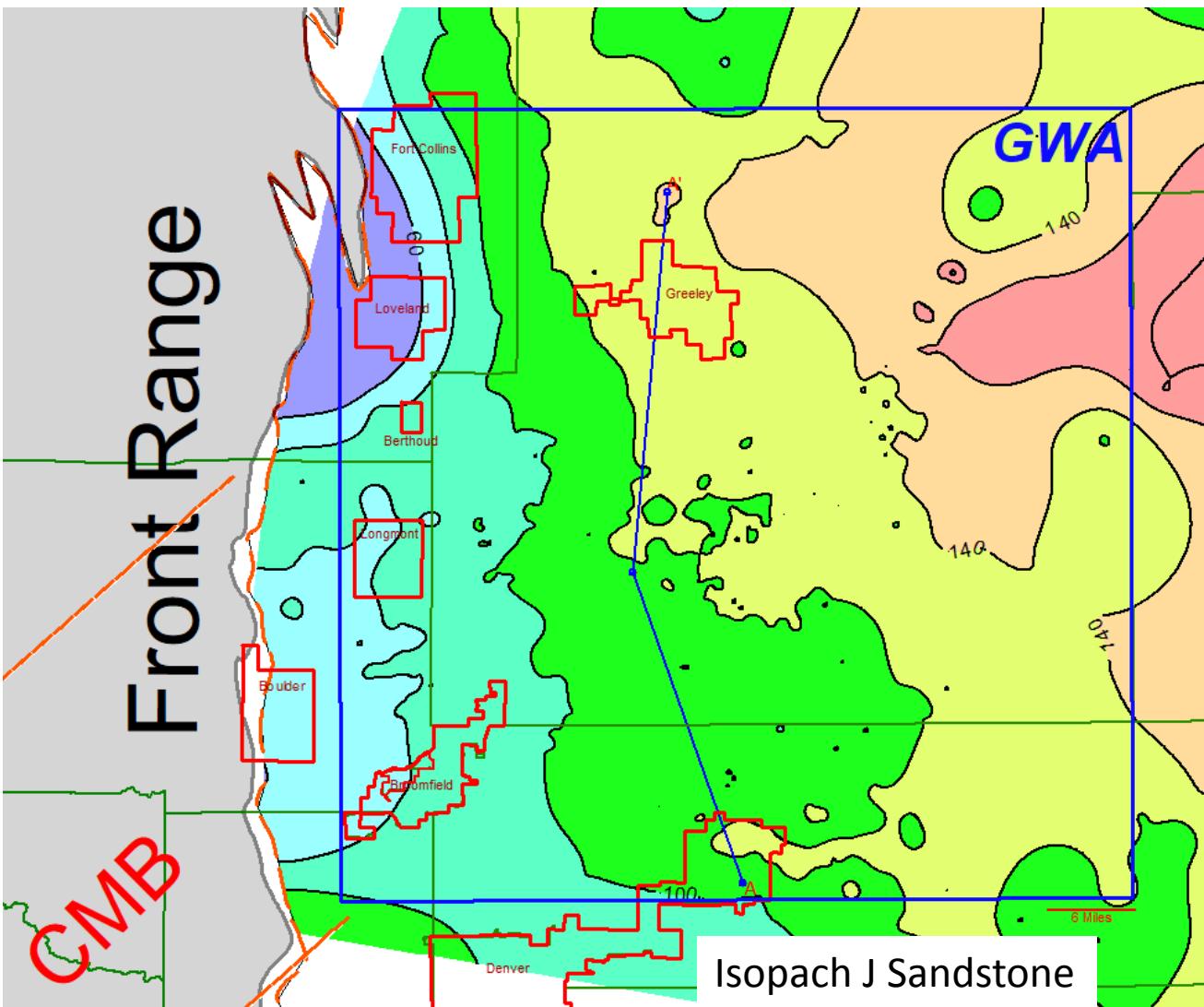
## Sec. 8, T1N-R67W



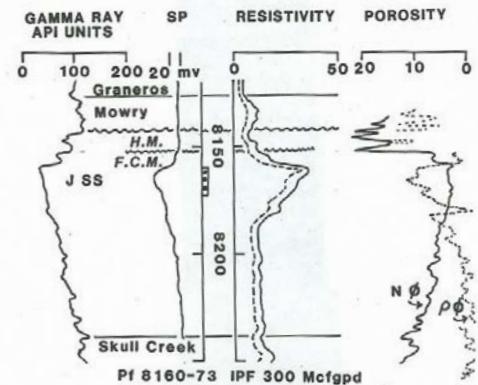


Muddy "J" sweet spot (> 500 MMCFG)

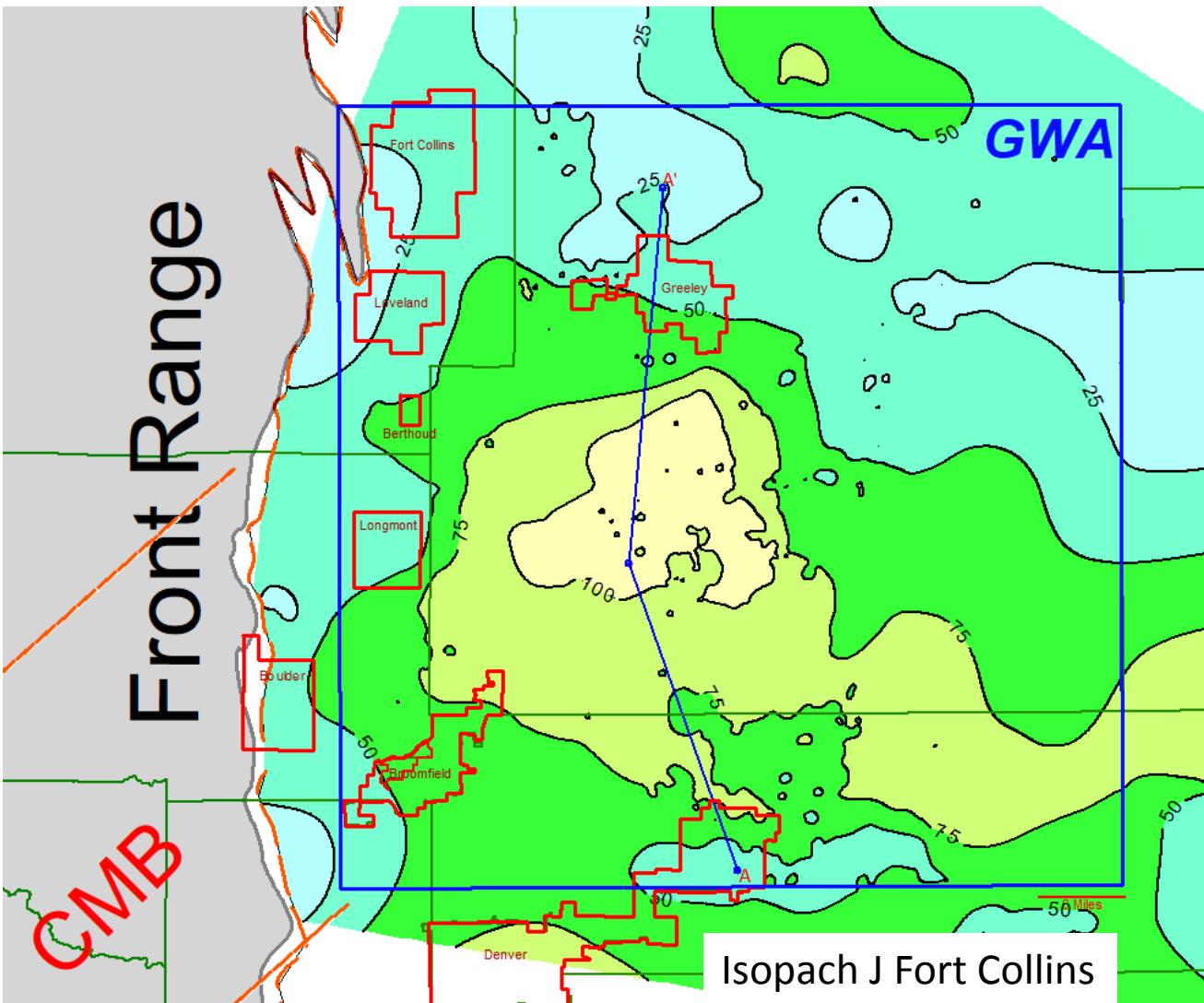
# Front Range



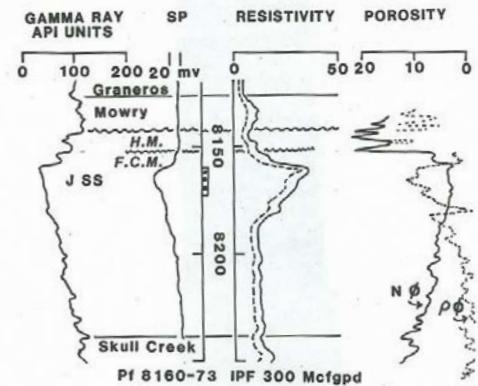
AMOCO #1 ROCKY MTN FUEL  
Nw Sw Sec. 8-T1N-R67W

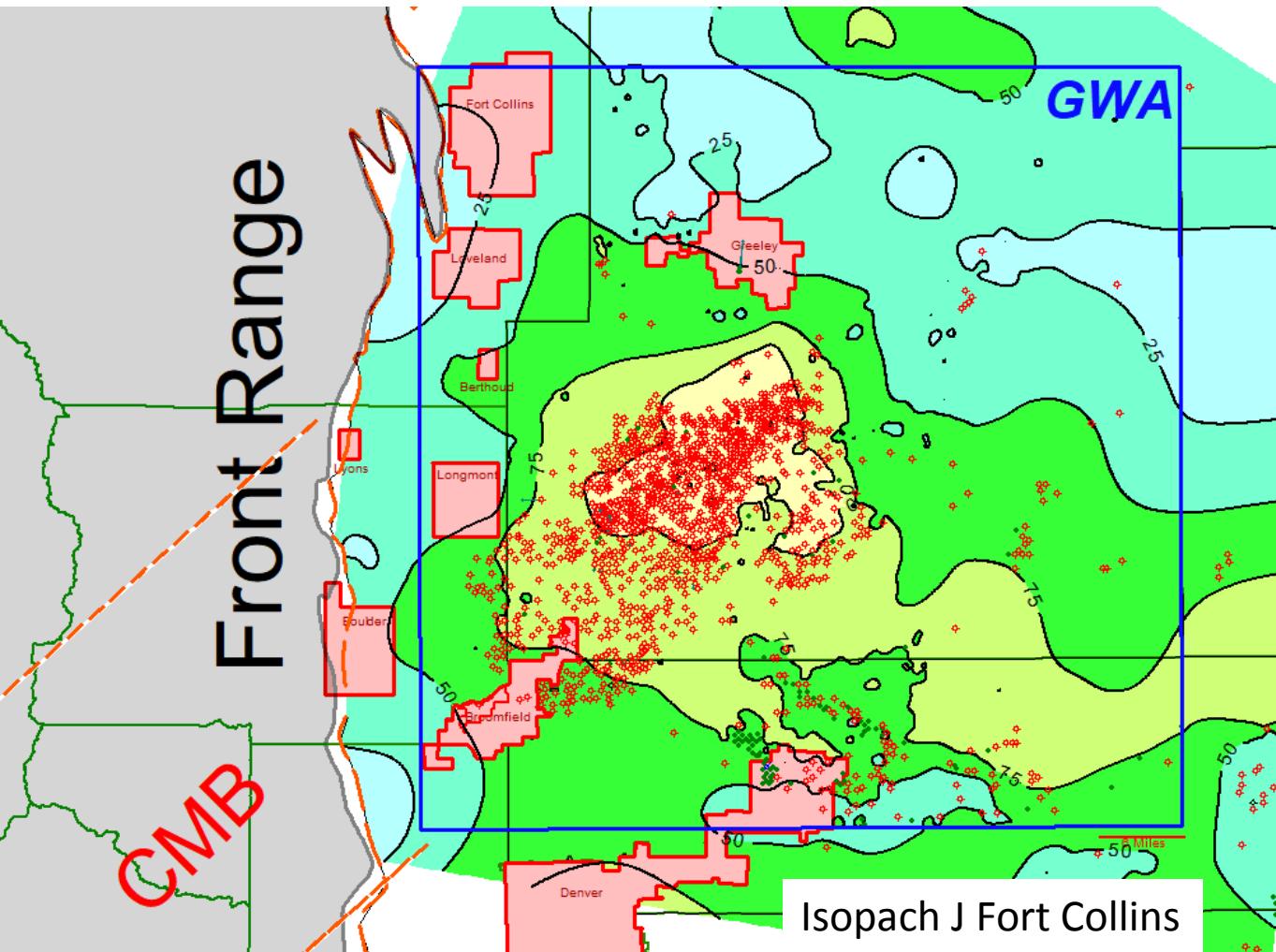


# Front Range

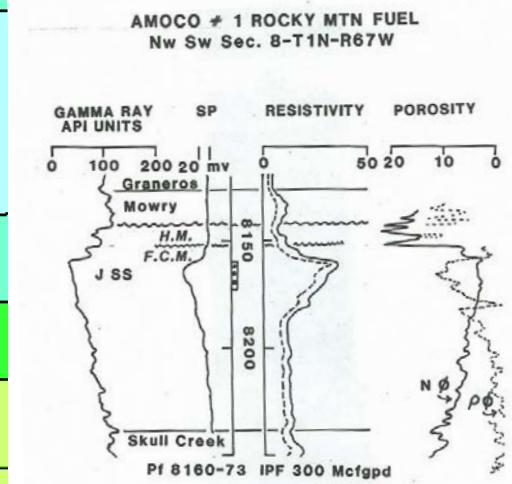


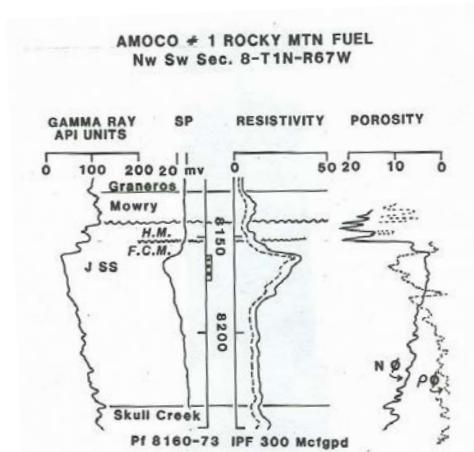
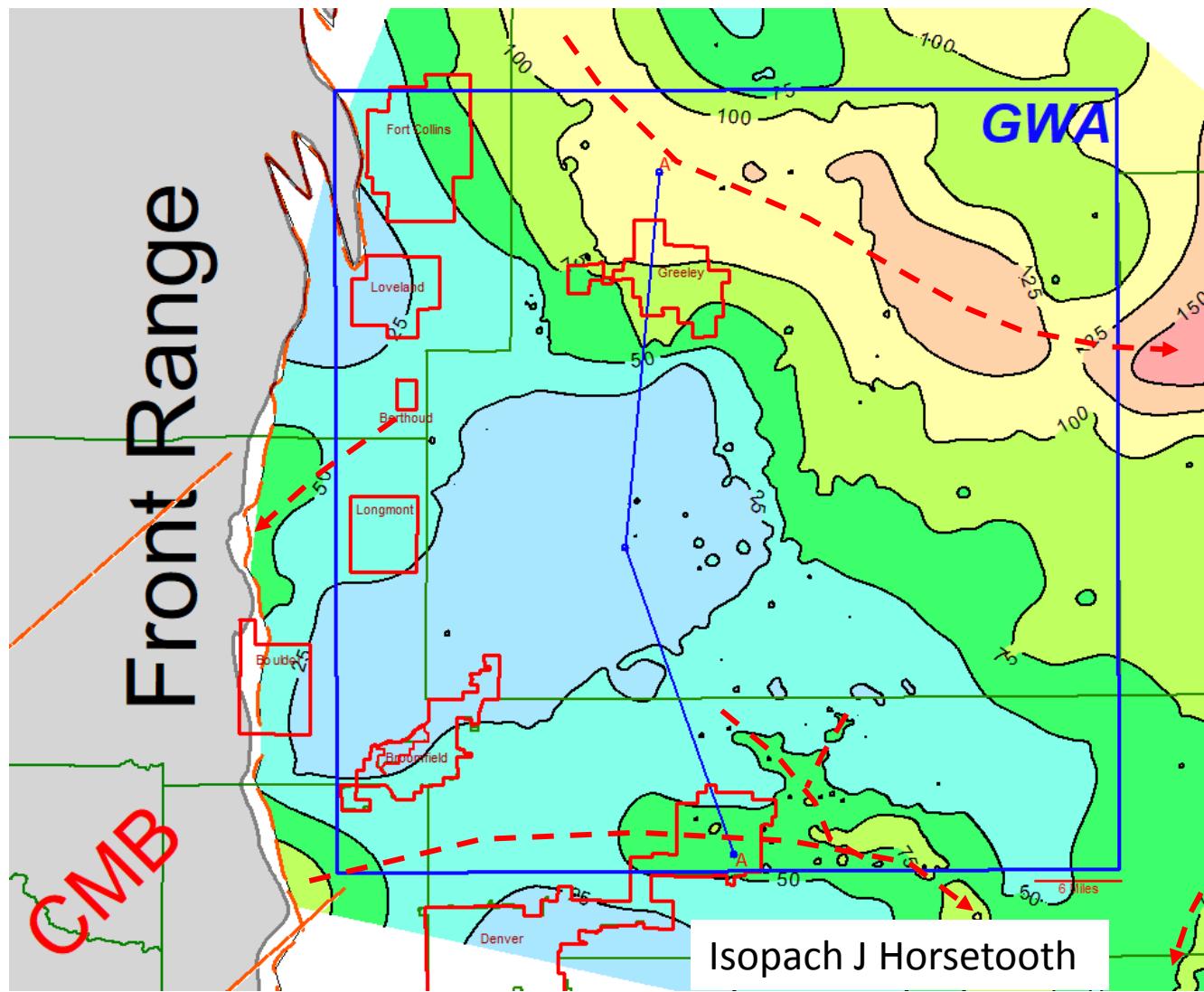
AMOCO #1 ROCKY MTN FUEL  
Nw Sw Sec. 8-T1N-R67W

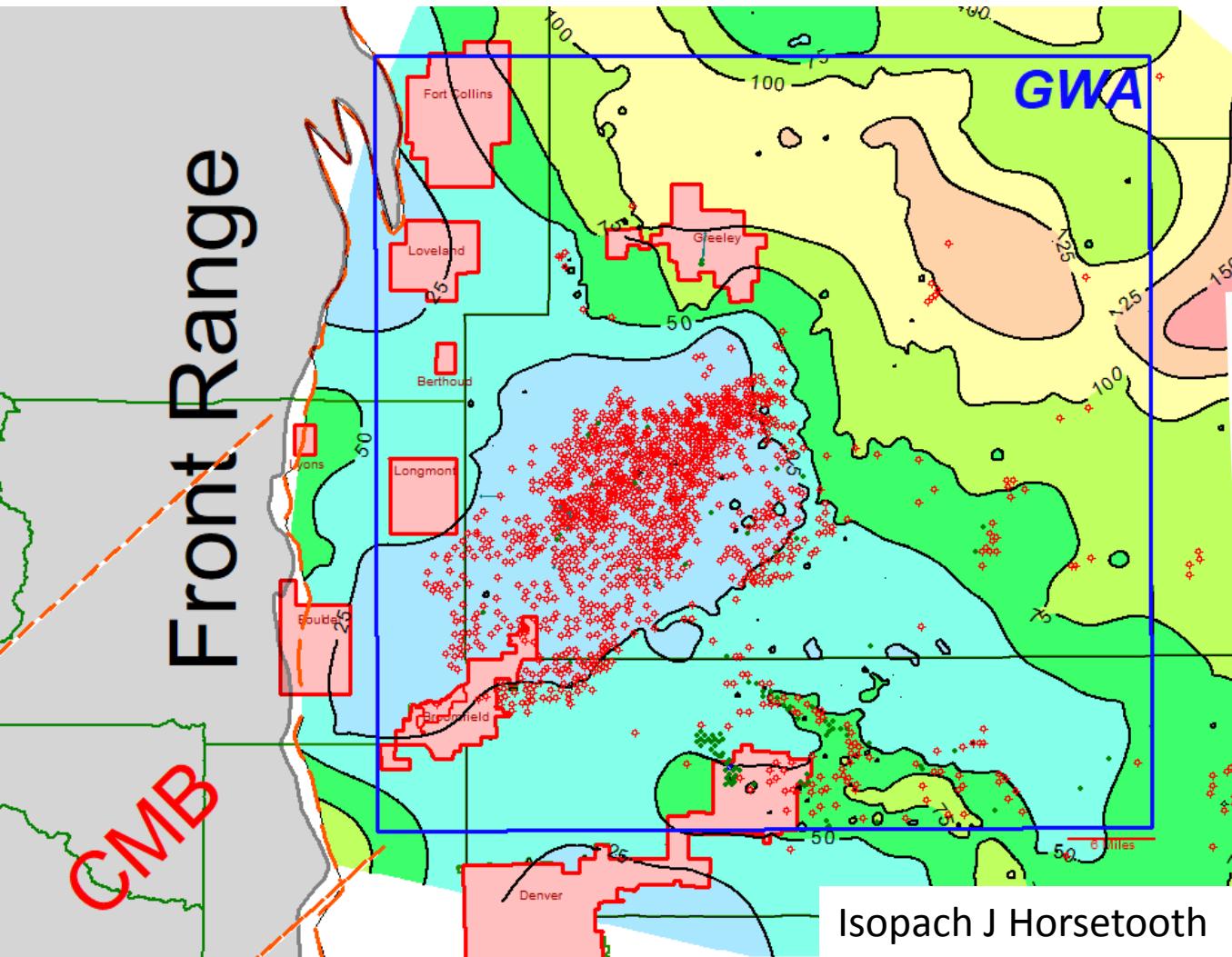




Gas symbols for wells cum prod > 500 MMCFG







## Gas symbols for wells cum prod > 500 MMCFG

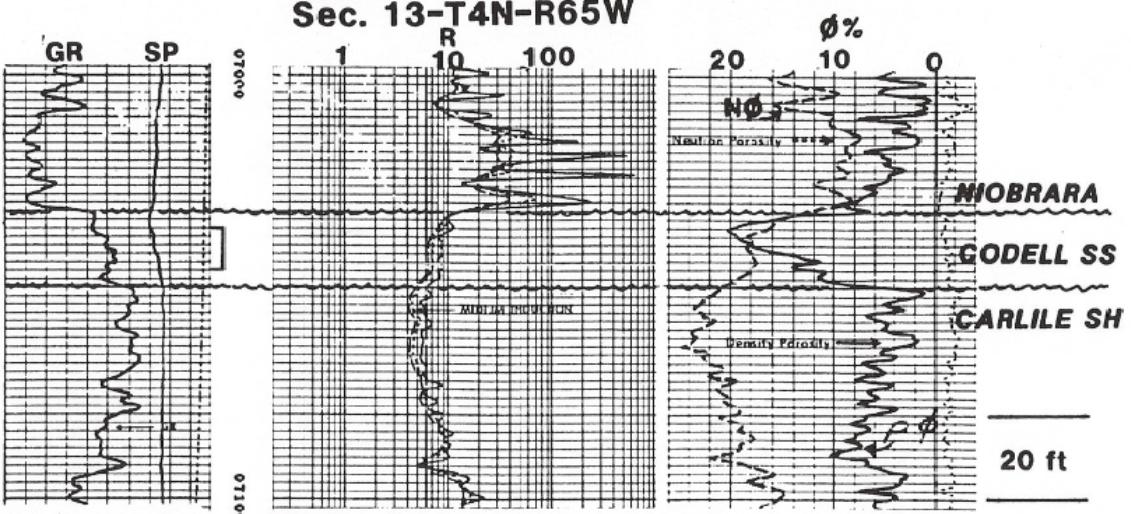
# Basic Reservoir Data, Codell SS

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• Depth	7,100 ft
• BHT, °F	260
• Gradient	0.5 – 0.65 psi/ft
• Gross sand, ft	10 to 30
• Net pay, ft	10 to 20
• Porosity, %	6 -12
• Permeability, md	0.05 – 0.005
• Port $r_{35}$	0.126 $\mu\text{m}$
• Original spacing	80 acres
• Current spacing	< 20 acres

A.

DOME # 1-13 FRANK  
Sec. 13-T4N-R65W

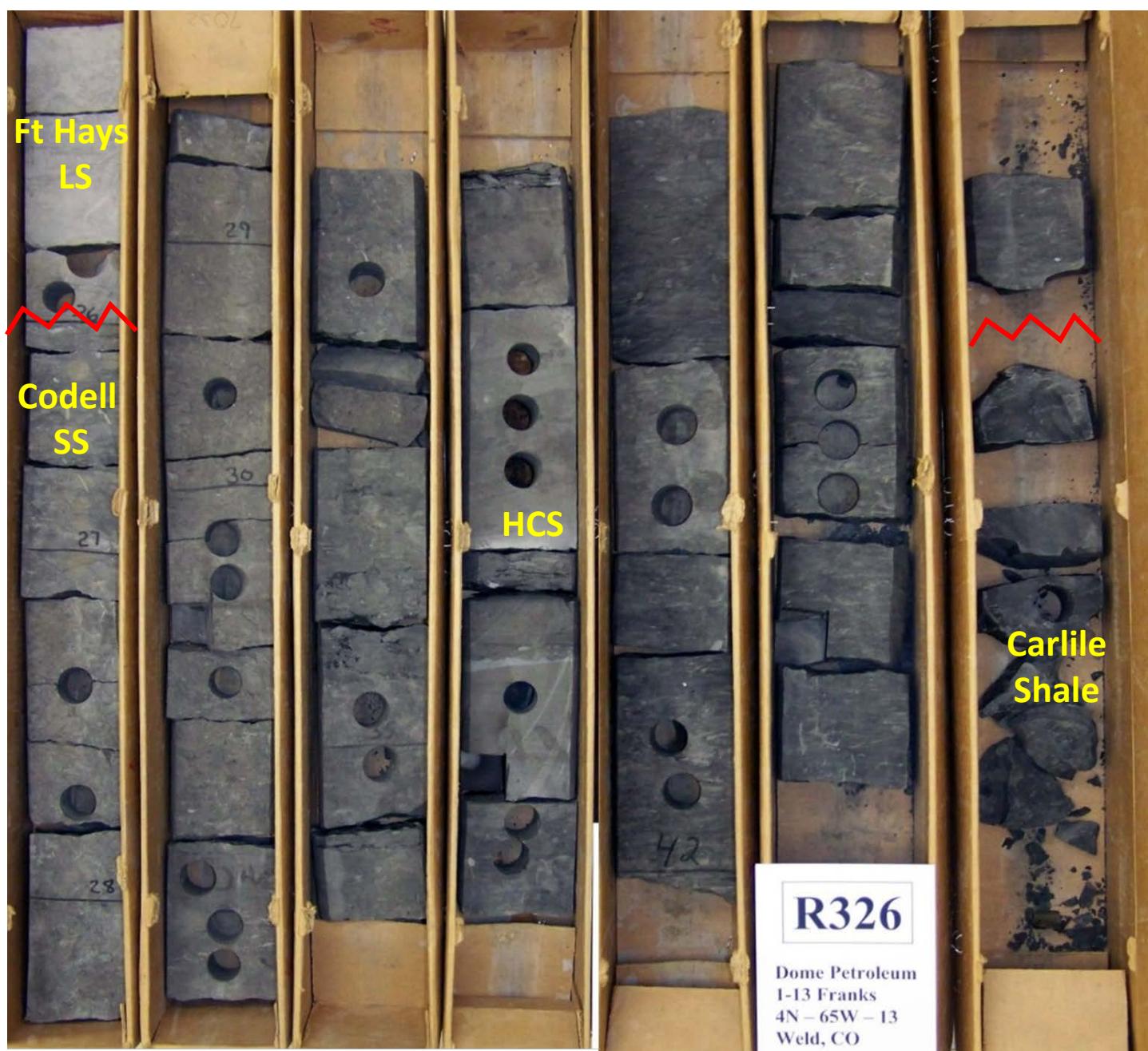


Pf: 7036-46 IPF 76 BOPD, 650 MCFGPD, GOR 8552,  
gty 60 FTP 2800

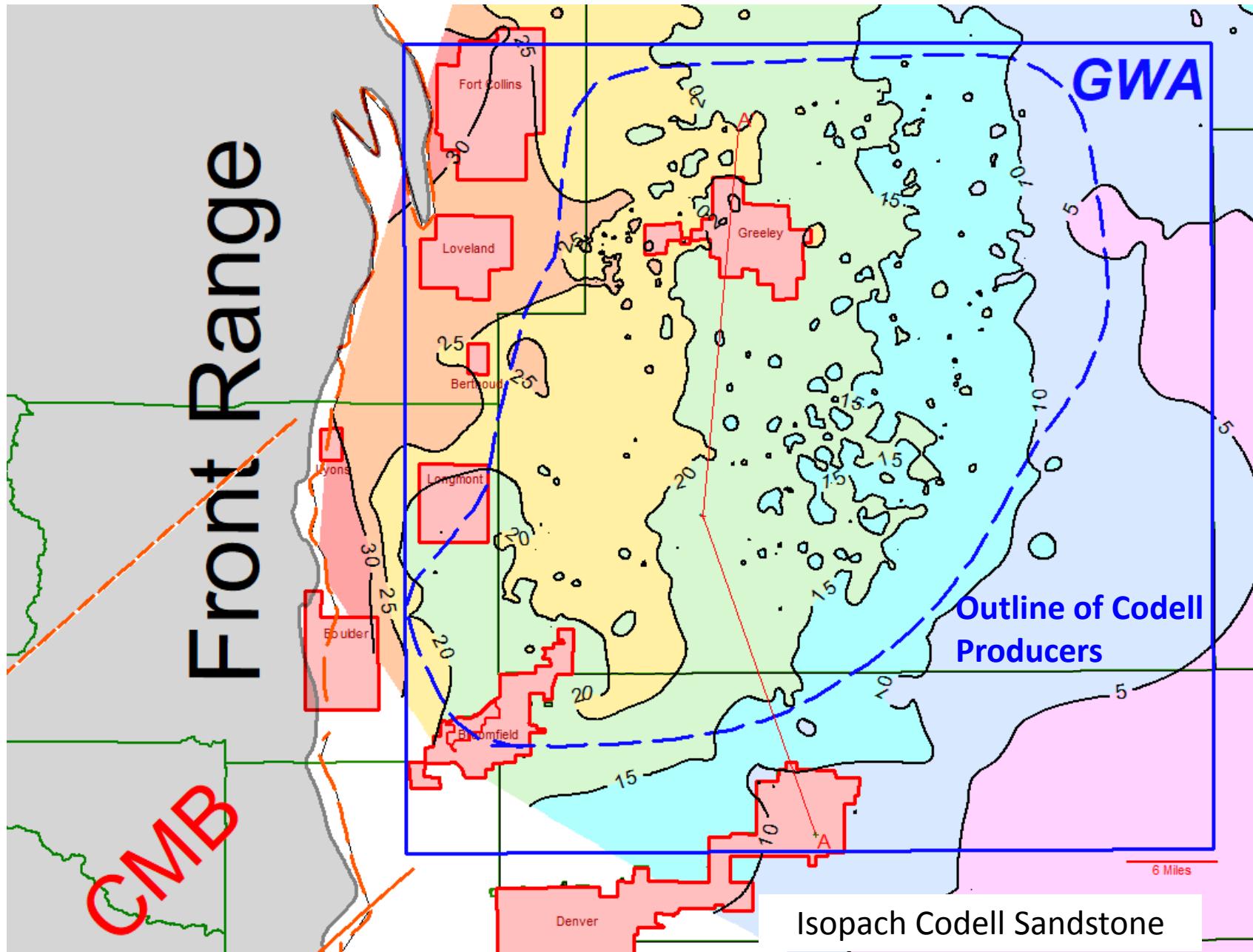
B.

Well Number:	Dome Franks #1-13		
	7030'	7031.5'	7037'
<b>Whole Rock Mineralogy</b>			
Quartz	77	69	75
Potassium Feldspar	-	-	-
Plagioclase	6	7	7
Calcite	4	9	5
Siderite	-	-	tr
Pyrite	tr	tr	-
Illite-Smectite	11	12	9
Illite+Mica	2	2	2
Kaolin	tr	tr	tr
Chlorite	1	2	2
<b>Relative Clay Abundance</b>			
Illite-Smectite	77	75	70
Illite	11	14	15
Kaolin	2	1	-
Chlorite	9	11	14
% Smectite in Illite-Smectite	25-30	25-30	20-25

*"More than 80% of the porosity has pore throats smaller than 0.25 µm in diameter"*  
*(Pagano, 2006)*

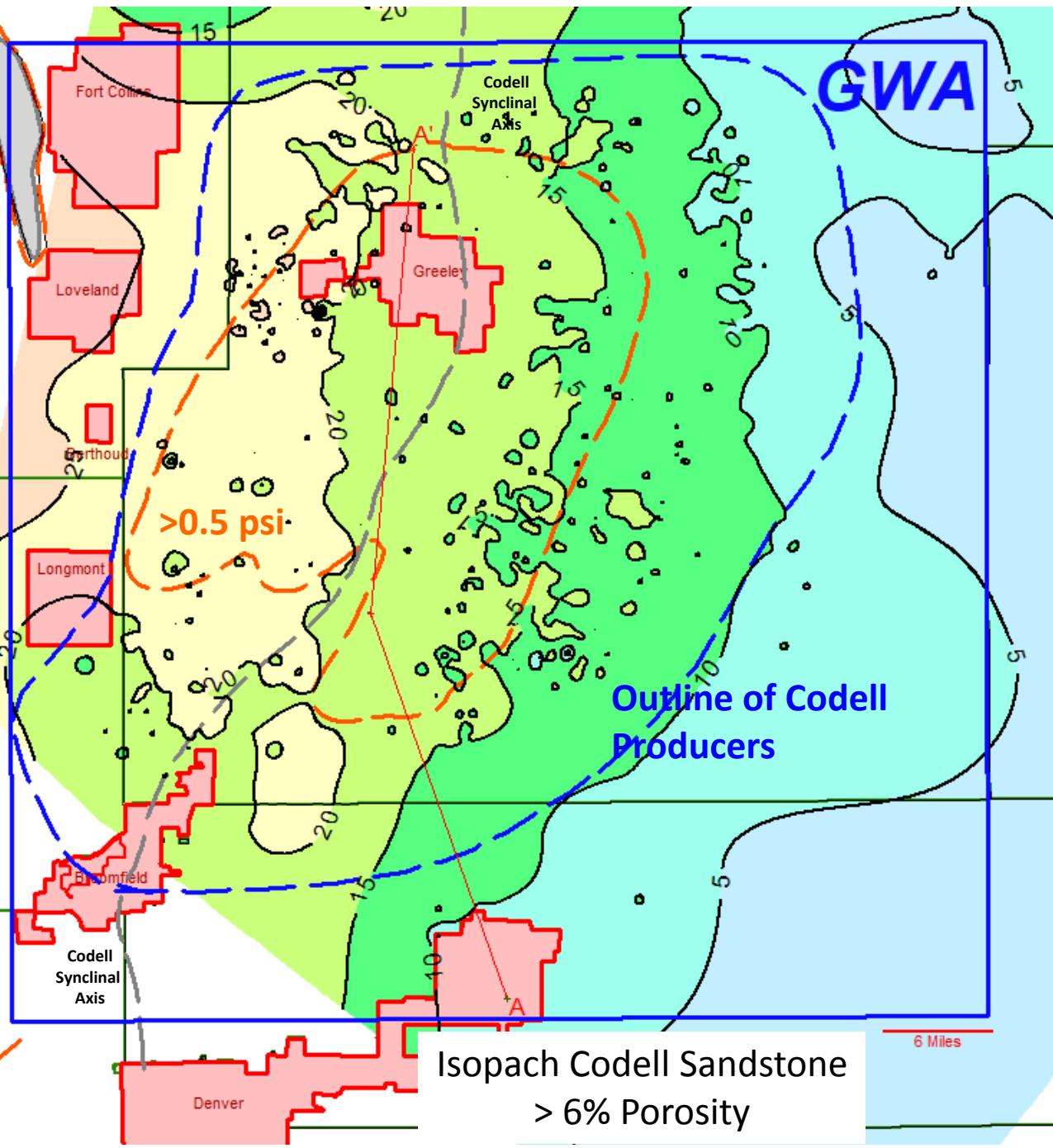


Burrows: *Teichichnus/Asterosoma*, *Planolytes*



# Front Range

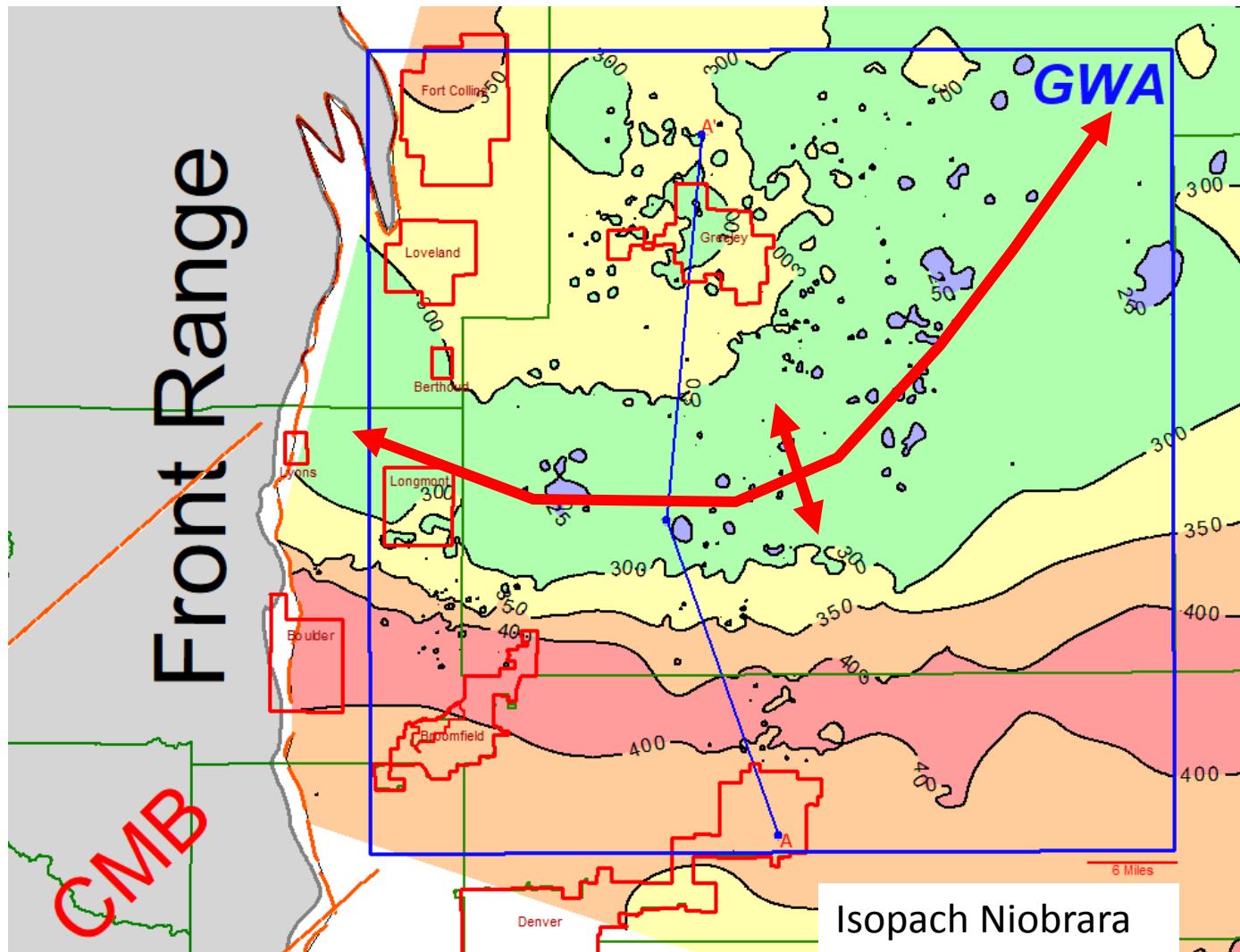
CMB



# Basic Reservoir Data, Niobrara

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• Depth	6,800 - 7,100 ft
• BHT, °F	260
• gradient	0.5 – 0.65 psi/ft
• Gross, ft	20-40
• Net pay, ft	20
• Porosity, %	6 -9
• Permeability, md	0.05 – 0.0005
• Original spacing	80 acres
• Current spacing	< 20 acres

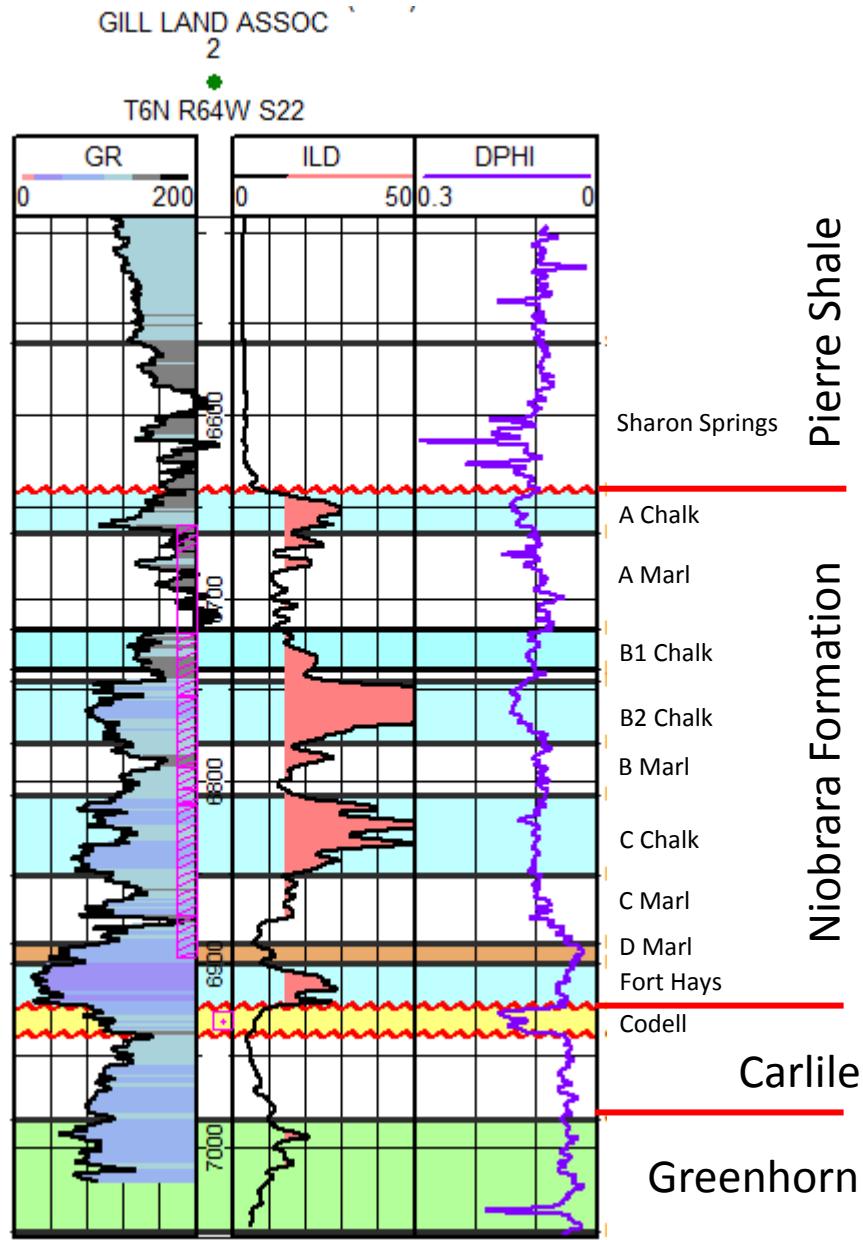


The diagram illustrates a geological cross-section with the following layers from top to bottom:

- Pay:** PIERRE SHALE (grey)
- SUSSEX (TERRY) SS:** (orange)
- PIERRE SHALE:** (grey)
- SHANNON (HYGIENE) SS:** (orange)
- PIERRE SHALE:** (grey)
- Sharon Springs Member:** (grey)
- NIOBRARA "A":** (cyan)
- SR:** (grey)
- NIOBRARA "B":** (grey)
- SR:** (grey)
- NIOBRARA "C":** (cyan)
- SR:** (grey)
- FT HAYS LIMESTONE:** (cyan)
- CODELL SAND:** (orange)
- CARLILE SHALE:** (grey)
- BRIDGE CREEK LS:** (cyan)
- HARTLAND SHALE:** (grey)
- LINCOLN LS:** (cyan)
- GRANEROS SHALE:** (grey)
- D Sand:** (yellow)
- J<sub>3</sub> SAND:** (yellow)
- J<sub>2</sub> SAND:** (yellow)
- Source Rock:** SKULL CREEK SHALE (grey)
- Source Rock:** DAKOTA SAND (orange)

**Typical Depth:**

- SUSSEX (TERRY) SS: 4300'
- SHANNON (HYGIENE) SS: 4800'
- Sharon Springs Member: 6800'
- NIOBRARA "A": 6800'
- FT HAYS LIMESTONE: 7100'
- CARLILE SHALE: 7600'
- GRANEROS SHALE: 7600'
- SKULL CREEK SHALE: 7800'

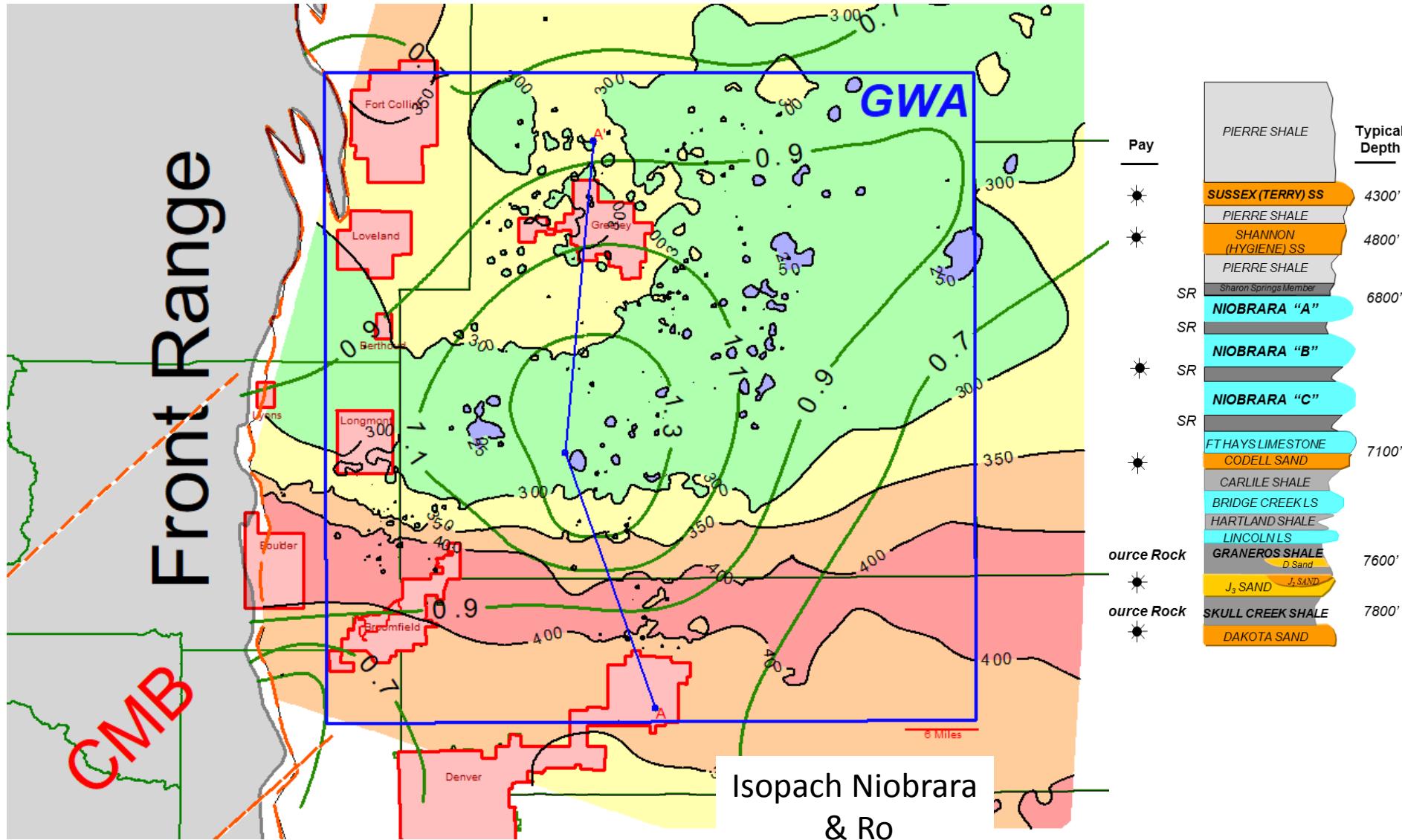


Pierre Shale

Niobrara Formation

Carlile

Greenhorn

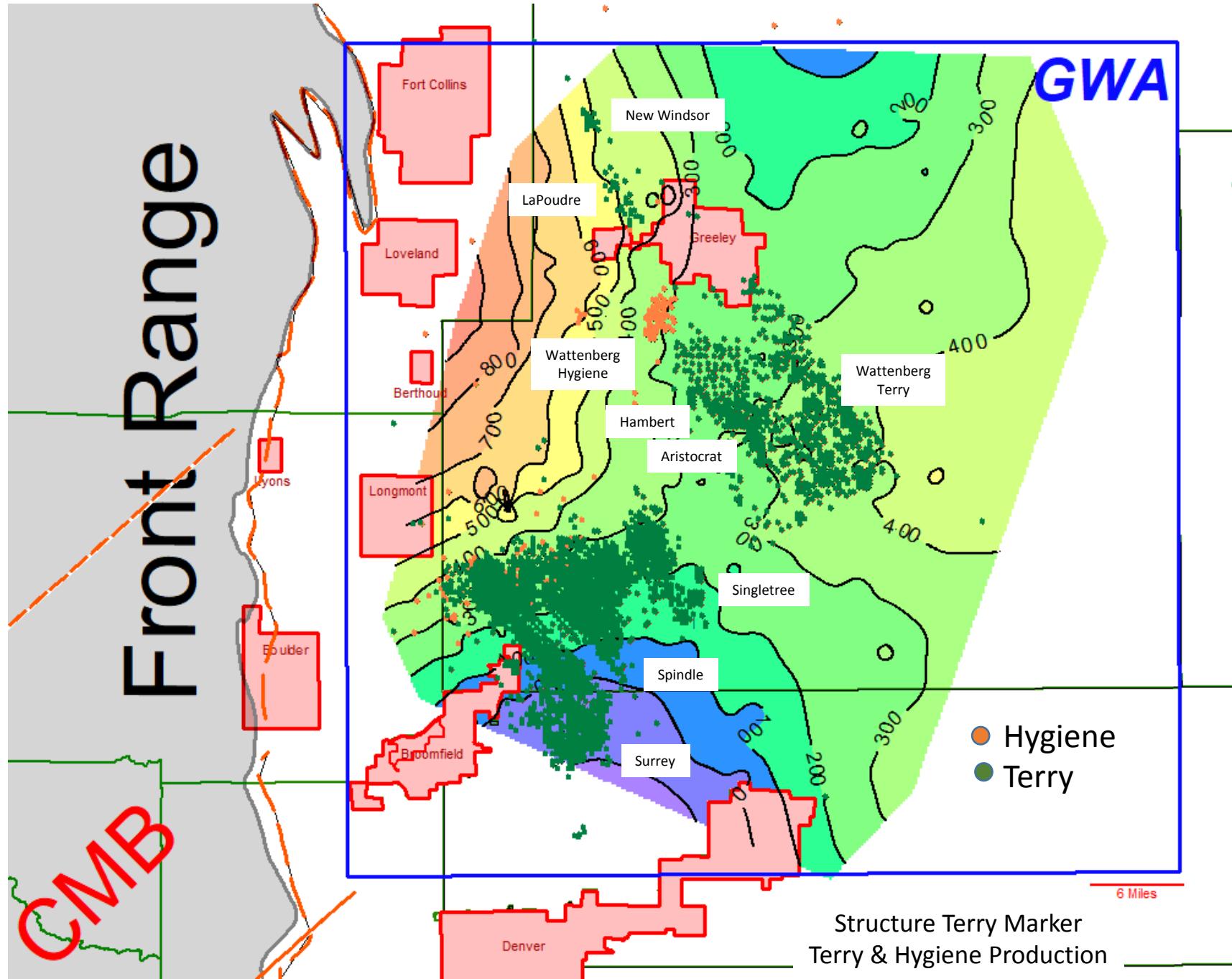


# Basic Reservoir Data: Terry & Hygiene

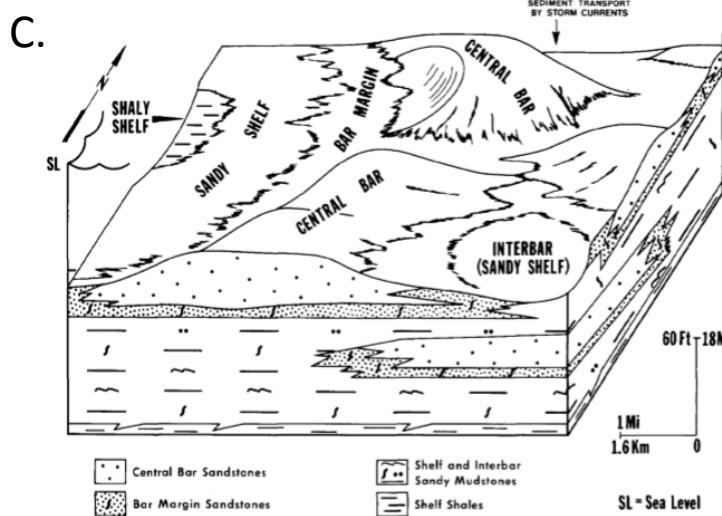
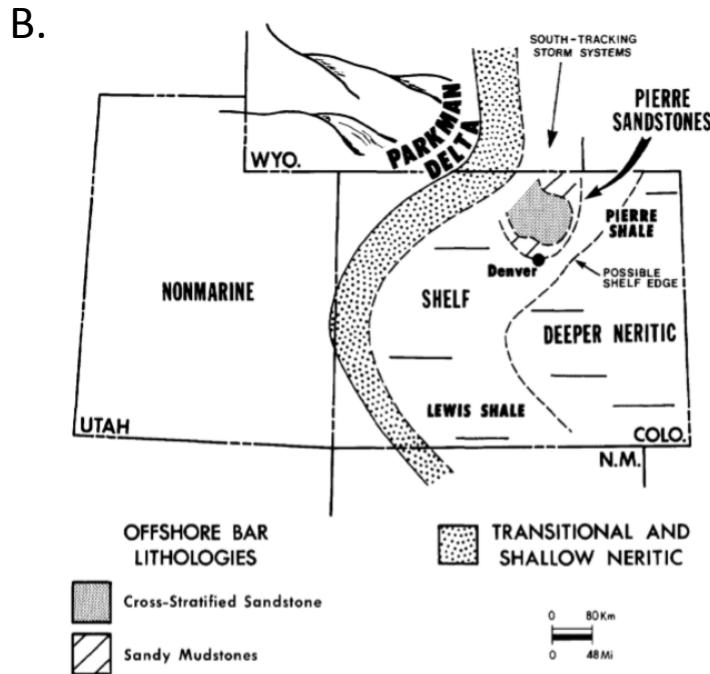
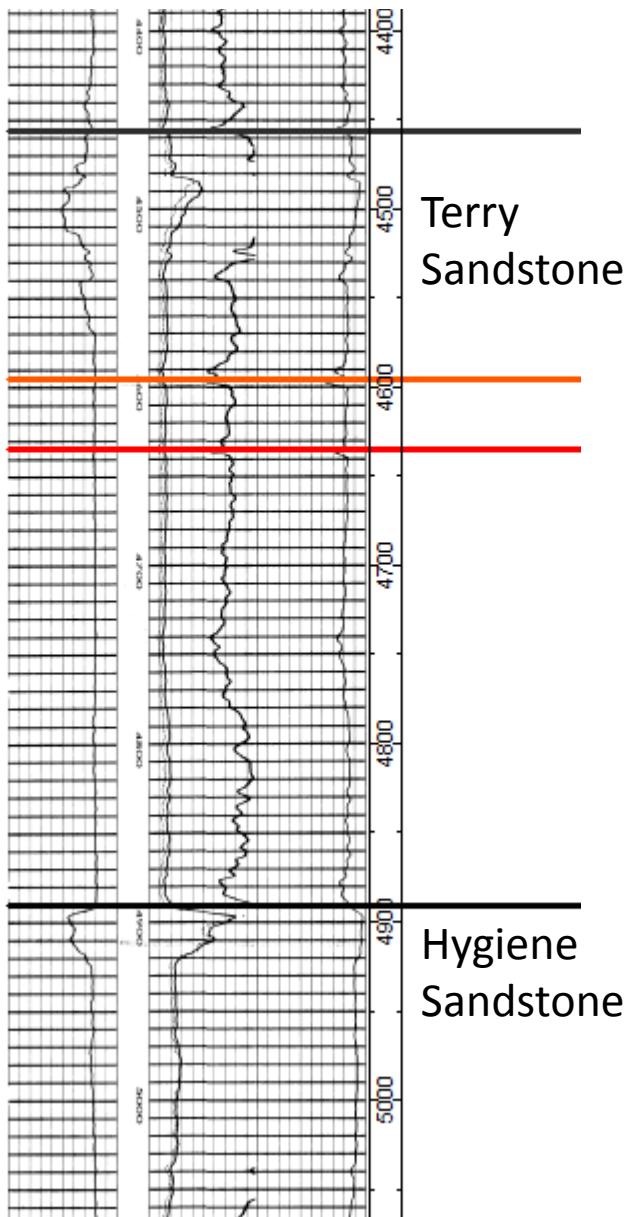
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• Depth	4,300 – 4,800 ft
• BHT, °F	120 -160
• Gradient	Normal
• API gravity	40-43°
• Gross, ft	20-25
• Net pay, ft	20
• Porosity, %	13 - 15
• Permeability, md	1.2 – 5.4
• Drive	Solution gas
• Original spacing	80 acres
• Current spacing	< 20 acres

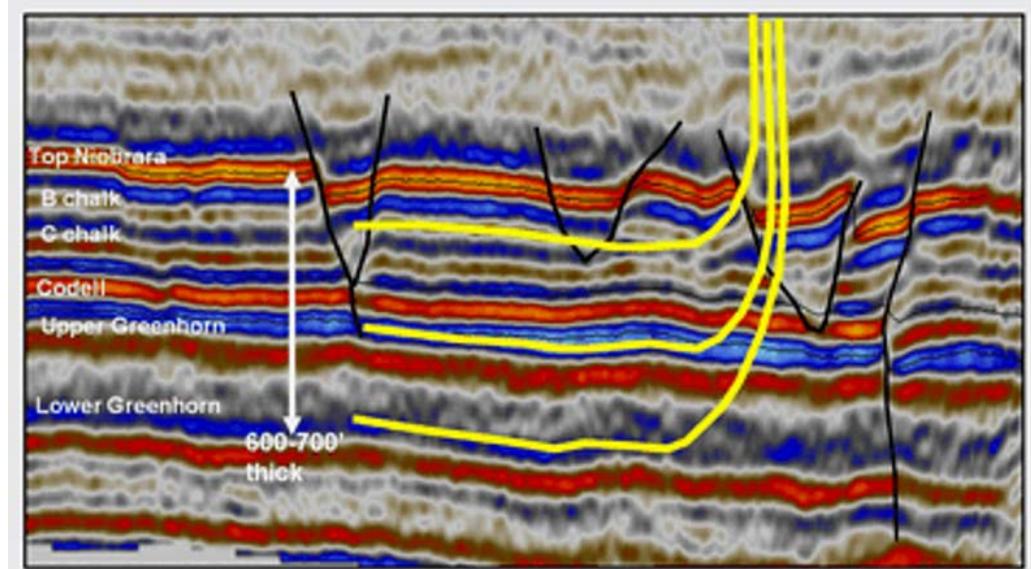
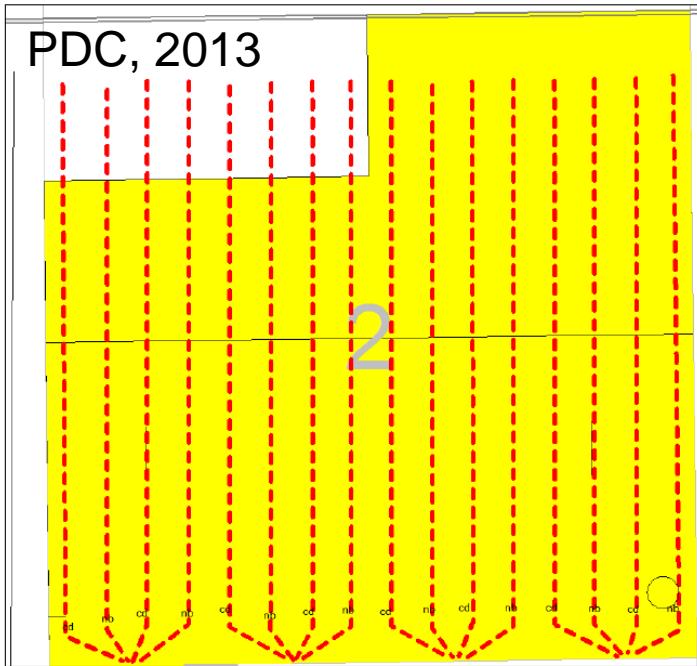
# Front Range



Amoco  
A. Rocky Mtn. Fuel D-7  
Ne SwSw Sec. 19=T2N-R67W

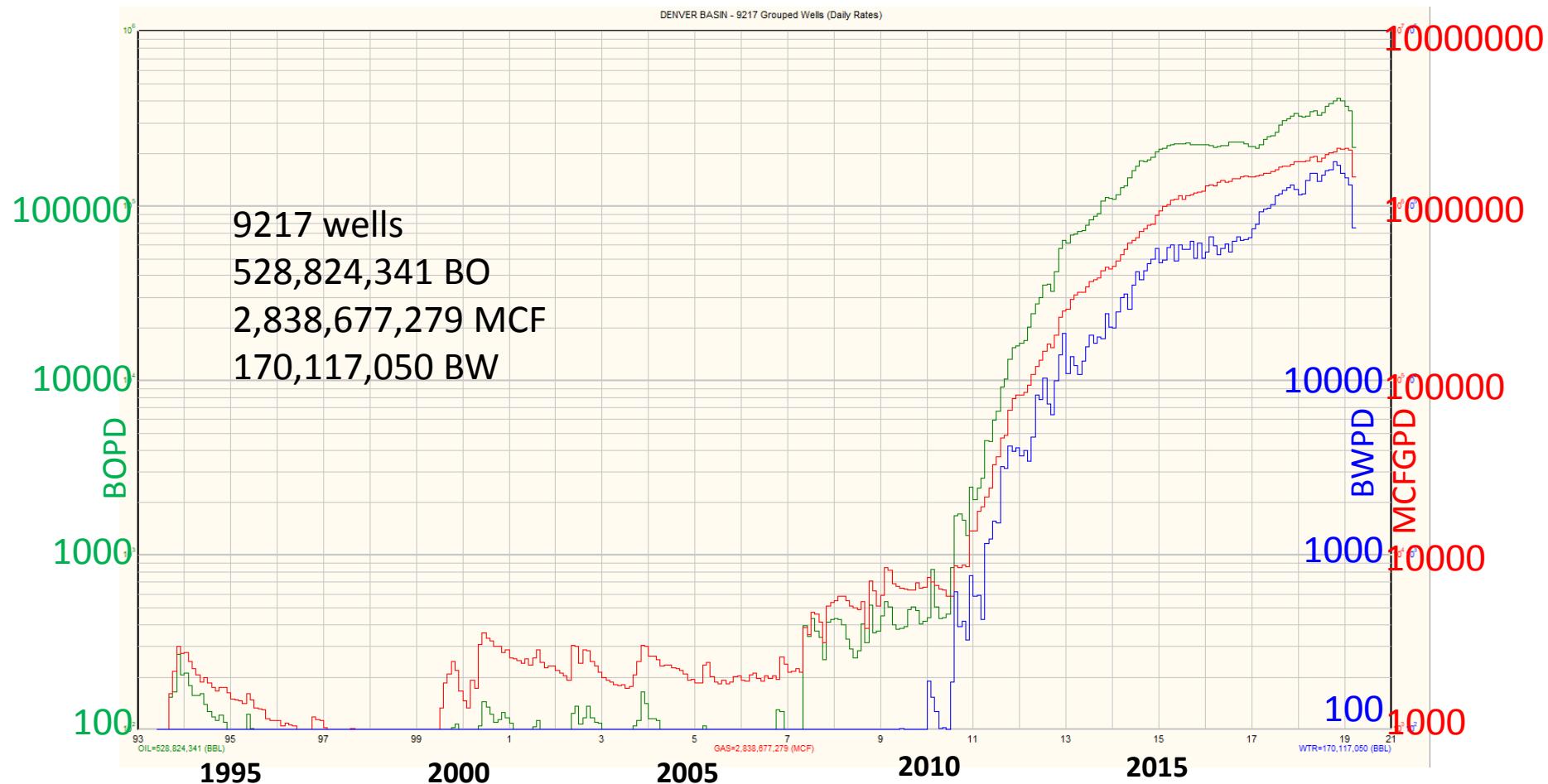


# The "New" Horizontal Play Another Game Changer



- 8 wells per 320 acres
- Alternating Codell & Niobrara
- Laterals about 335' apart
- Using tracers & fracture mapping

# Wattenberg Field Horizontal Production



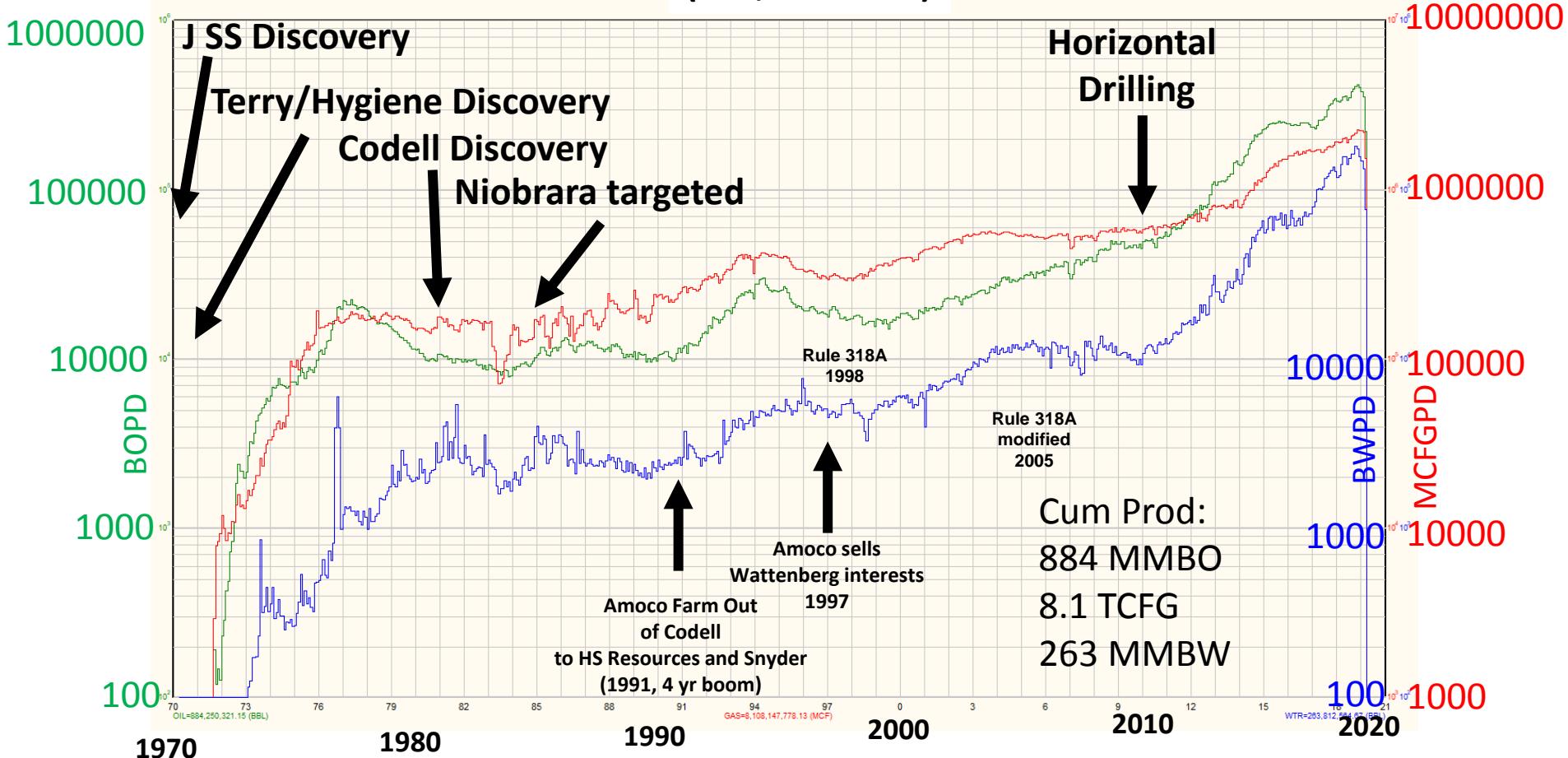
# Summary

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- Long history of development in a basin center continuous type of play
- GWA = 2.3 BBOE cumulative
- Temperature anomaly, excellent source beds, tight reservoirs
- Wattenberg High paleostructure
- Infill drilling, new horizons, new technology, refracs, changing operators
- Horizontal drilling and multistage fracture stimulation are key drivers
- Wattenberg Field is seeing a new beginning because of the Niobrara & Codell (another 4-5 BBOE)
- New reserves are found in old fields with new technology and ideas!

# Wattenberg Field Production

(~40,000 wells)



# Drilling Permit Moratoriums & Fracking Bans

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- Drilling Permit Moratoriums
  - Broomfield
  - Erie
  - Superior
  - Lafayette
  - Berthoud
  - Timnath
  - Boulder County
  - Adams County
- Fracking bans
  - Boulder
  - Lafayette
  - Fort Collins